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TRANSACTIONS

OF THE

NEW ZEALAND INSTITUTE.

On *Turbo postulatus* Bartrum: Does it indicate a Pliocene Connection with Australia?

By H. J. Finlay, D.Sc.

[*Issued separately, 23rd May, 1931.*]

In his original description of the Mid-Pliocene molluscan fauna of Kaawa Creek, Professor Bartrum (*Trans. N.Z. Inst.*, vol 51, p. 100; Pl. 7, Fig. 14, 1919) included a very curious form as "*Turbo* (?) *postulatus* n. sp." The first material was fragmentary, and little could be said except that it "appeared to the writer to represent a species of *Turbo*." Since then Bartrum and Powell (*Trans. N.Z. Inst.*, vol. 59, p. 141, 1928, have revised the entire fauna of this interesting locality, but were unable to suggest a suitable generic location for this species. After examination of more plentiful and better preserved material, they noted several features discordant with its reference to *Turbo*, and suggested a general likeness to *Tonna*, though here again pointing out discrepancies in columella, basal notch, and especially size. So that even the family to which this anomalous shell belongs is still doubtful. Up till now, no related form has been pointed out, and the species has been regarded as a sudden stray occurrence in our fauna. I am now able to point out a very close Australian relative, and a probable New Zealand one also, which very much enhances the significance of this fossil and its solitary occurrence in the Waitotaran stage in New Zealand.

In 1893, Professor Tate, in describing the Tertiary Naticidae of Australia proposed a new genus *Heligmope*, for the sole species *H. dennanti*, which he there described from the Upper beds at Muddy Creek (*Trans. Roy. Soc.*, vol. 17, p. 329; Pl. 7, Figs. 5, 5A, 1893) and also Hallett's Cove, St. Vincent's Gulf. It is probable that more than one species occurs in Australia, since Tate mentions that the Hallcett's Cove specimens are generally more depressed and have sub-obsolete sculpture; on this account he selected the Muddy Creek figured specimens as types. The inclusion of all these forms under the one name gives rather wide specific limits to the diagnosis, which, in fact, could quite easily cover also the New Zealand *postulatus*. All the New Zealand shells, however, seem to be depressed and feebly sulcate, thus coming nearest to the Hallcett's Cove form, and in the absence of Australian specimens for comparison, it is even difficult

to detect distinguishing specific features. Except that in *postulatus* the spiral ribs are equal to or broader than the interstices while in *dennanti* they are stated to be narrower, there would seem to be little difference between these two very closely related forms.

Now, any genera that contain like forms on opposite sides of the Tasman Sea, whether in times past or present, are full of interest to the stratigrapher and the regional geologist, but not all these genera are of equal value on which to base correlationary hypotheses. For instance, many forms of *Dentalium* and *Natica* from Tertiary beds in New Zealand can be almost exactly matched by Australian fossils, but this proves little, for these two evolutionary lines are very long and wide-ranging, and have comparatively narrow limits of specific variability. Although, for example, *Natica* (*Cochlis*) *notocenica* Finlay is with difficulty separable from *N.* (*C*) *subnoae* Tate as a species, yet their ancestors and descendants in each country are more easily separable, and it is unwise to lay much stress on a similarity perhaps brought about by chance.

But when the genera concerned are short-ranging and highly distinctive, the matter is on a different footing altogether. Much less allowance can be made for convergence, environment, etc., and one seems justified in deducing a somewhat near relationship between the species concerned. In the present case, *Heligmope* satisfies both conditions, and is as excellent an example as could be wished for. Its ancestry is quite problematical, it suddenly appears in both countries at about the same time (Lower Miocene) it gave rise to but few species, all very similar, it is so outstanding a genus that even its relationships have puzzled every observer, and it very rapidly dies out again. It is, in fact, quite comparable with the American genus *Orthaulax,* which for much the same reasons has for long been regarded as an "index fossil." Woodring (*Pub. No. 385, Carnegie Institution of Washington,* p. 91, 1928) says of it that "the dangers of relying too much on the range of one genus are fully recognised," but that "*Orthaulax* has turned out to be particularly valuable" for much the same reasons as I have mentioned in the case of *Heligmope*. There is, therefore, no reasonable room for doubt that the genus *Heligmope* must have arrived in one of its countries very soon after its inception in the other. Whether it had its origin in Australia or New Zealand is at present problematical, as it is not yet possible to determine which of the horizons is the older. Chapman and Singleton (*Proc. Pan-Pac. Sci. Cong.*, Australia, 1923, vol. 1, pp. 3 and 8, 1925) place both the Australian localities in the Kalimnan, which they regard as Lower Pliocene; Marwick (*Trans. N.Z. Inst.*, vol. 57, pp. 573 and 576, 1927) puts the Kaawa beds in the Waitotaran, which he places as the lowest of his three Pliocene divisions.

If it is granted, then, that [illegible] forms of *Heligmope* in New Zealand and Australia are pract[illegible] contemporaneous, and so closely allied that there has been lit[illegible]ne for evolutionary change, also that the chance of convergence [illegible] be here ruled out, we are left with an interesting deduction. Tate [illegible]ated that the genus "may be described as an imperforate *Euna*[illegible]*na,* or a *Sigaretus,* with a sinuated

front margin, and stands in relation to it as *Protoma* does to *Turritella*." Now if either this contention, or that of Bartrum and Powell, that the genus is related to *Turbo* or *Tonna*, be correct, it follows that there must have been an easy and direct method of connection between the two countries in the Pliocene! This is so radically counter to the opinions of geologists past and present that it is worth careful consideration; yet from the evidence the deductions so far made seem impossible to avoid. Both Naticoids and Turbinid shells are littoral and sub-littoral dwellers and slow progressors, and would be effectually barred by any depth of water; their young are also mostly seaweed and sandy beach frequenters and there is no evidence that they are much carried about by currents—rather the reverse. To allow of their progress over the 1200 miles between New Zealand and Australia, one would have to postulate a connection not only of shallow waters and sandbanks, but also of so direct a path that climatic conditions had little play. The species of these groups are inclined to be so local that the change of temperature produced by but a few degrees of latitude, almost always modifies or exterminates them. The suggestion of alliance with *Tonna* (inherently improbable however, from shell features) would dispose of a few of the difficulties but not many. Powell (*Trans. N.Z. Inst.*, vol. 57, p. 559, 1927) has recorded the appearance of a Recent Australian species of *Tonna* (*tetracotula* Hedley) in New Zealand waters and remarks, "That Recent conditions are still favourable to the immigration of Australian species *of certain types* (italics my own) is indicated by the three species . . . . recorded in this paper." Strangely enough, one of these is a *Natica*, but it is of a widely spread subtropical type, and differences can be seen between New Zealand and Australian examples, so that it is more likely an immigrant from the north. But even supposing that *Heligmope* is of Tonnid affinities and followed the same methods of distribution, it is necessary to invoke a favourable ocean current, and this at once brings us to a standstill again. For in the first place any such ocean current influence (as I have already described in the *Verbeek Gedenkboek*, p. 166, 1925) does not seem to have antedated the Castlecliffian stage. Those species which may reasonably be assumed, from evidence elsewhere and from embryonic characters, to be readily transported by currents* belong to such families as the Cymatiidae, Muricidae, Architectonicidae, Thaididae, etc., and while the bulk of those that are identical or nearly identical with Australian species occur only as Recent or Pleistocene shells in New Zealand, there are already a few such as *Cymatium spengleri*, *Mayena australasia*, and "*Typhis*" *zealandicus* Hutton which are present in the Castlecliff beds. But no member of this class of shell occurs, as far as we yet know, at Nukumaru, the horizon following directly below, and even at Castlecliff the Australian influence is negligible compared with

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*Woodring (*l.c.*, p. 103) remarks, "It seems reasonable to believe that the larval stage of gastropods that have a large 'nucleus' consisting of many whorls such as the frog-shells, tritons, and tuns, lasts long enough to permit transportation under favourable conditions across the Atlantic in the track of the south equatorial current."

the number of migrants in Recent (and probably Pleistocene) times. *Fusitriton, Fusus, Galfridus, Agnewia, Austrotriton parkinsonia* and other *Cymatiidae, Hydatina, Philippia,* etc., are sufficient evidence of a post-Pliocene influx that was not possible during perhaps the whole of the Tertiary period. A suggestive statement in this connection is that made by Marshall and Murdoch (*Trans. N.Z. Inst.*, vol. 52, pp. 117, 118, 1920); "Three miles to the north of Kai-iwi an old land-surface can be seen distinctly in the stratification" (of the Wanganui Pliocene series) . . . . . "There is another instance . . . . near the south end of the Nukumaru Beach . . . . they show that there were temporary oscillations in the level of the land whilst the deposition of these rocks was in progress." Another suggestive fact is the statement made by Hodge Smith and Iredale (*Proc. Roy. Soc. N.S.W.*, vol. 58, pp. 157, 168, 1924) that "the nature of the evidence of a negative movement of the strand line of four hundred feet in New South Wales is both geological and biological . . . . A southern shore-line coexistent with the East Coast of Tasmania was drowned when Bass Straits were formed . . . . This . . . . took place certainly not earlier than Pleistocene and probably in quite recent times." I suggest that here are possible reasons for the formation of the present ocean current system in the Tasman Sea, and an explanation of the preponderatingly Recent occurrence of Australian migrants in New Zealand waters.

To return to *Heligmope*: in the second place, if such a favourable current is invoked in Waitotaran times, the question at once arises, Why did not other forms come across too? The gritty or sandy shallow water nature of the Kaawa Creek (and also Nukumaru) beds is much the same as the calcareous sands at Muddy Creek, (Upper) and Hallett's Cove, so that, apart from the (possibly) slightly colder climate, the ecological controls should have been fairly similar. But, so far as I know, not a single other species from Kaawa Creek is closely enough related to an Australian Kalimnan species to be worth comment; the species of such easily distributed genera as *Terebra, Murex, Olivella,* etc., belong to quite different lines of descent, and no Cymatiidae at all are present.

The ocean current hypothesis, then, is in this case out of the question, and once more we are brought back to the deduction that unless the animal of *Heligmope* was radically different in its habits from that of other shells of similar shape and approximate appearance, it seems inevitable that a direct connection across the Tasman Sea existed at some time in the Lower Pliocene. Yet this invites one of the same objections as the ocean current idea; why did not many other sub-littoral forms accompany *Heligmope* across and become established in New Zealand? Is any solution evident to this perplexing problem?

I have tried to build up the evidence in favour of this Pliocene connection not because I believe in it, but because I wish to demonstrate the danger of arguing thus about any genus, useful and outstanding though it may appear, before its natural affinities are truly known, or while any other interpretation can be given. There is one point about *Heligmope* that no observer has yet mentioned, and in

the absence of this one small but all important detail, the problem as I have outlined it would have to be left unsolved in an unsatisfactory and perplexing state. But I put forward a very simple solution. I suggest that *Heligmope* belongs to the Ianthinidae, and that the whole ensemble of shell features conclusively proves this. *Ianthina* has a very characteristic sinus on the periphery (though its near ally *Recluzia* has none), and at first sight *Heligmope*, in lacking this, differs considerably in the aperture and lines of growth. But push the sinus of such a species as *Ianthina ianthina* down on to the base, half-way between the columella and the periphery, and prolong the aperture downwards instead of sideways to correspond, and a very close approximation to *Heligmope* is obtained. Every other feature of *Ianthina* is present—the twisted pillar with the little basal lip and the thin spread of parietal callus; the same suture and prominent growth lines, more lamellose posteriorly; the obscure wide spiral ribs, though much reduced in *Ianthina*, especially above the periphery; and the thin fragile shell, still showing traces in some specimens of *postulatus* of the characteristic dark bluish-violet colour! Bartrum and Powell were unable to record the protoconch; I suggest that when a perfect specimen is found, the apex will turn out to be as in *Ianthina*, glassy, conically dome-shaped, of two or three whorls set quite oblique to the axis of the shell, and more or less immersed in the succeeding shell whorl.

The placing of *Heligmope* as a Tertiary genus of the Ianthinidae of course removes the difficulties arising out of its distribution. Ianthinas of the two groups *ianthina-violacea* and *exigua-capreolata* occur fairly commonly all round Northern New Zealand and are washed up on every Australian coast. A wide distribution is to be expected in all pelagic animals, and if *Heligmope* lived in the open waters of the Tasman Sea in the middle and late Pliocene, it is not curious, but normal, to find it in the shallow water beds of both countries. No connection of any sort need be postulated, and there is no longer an annoying problem.

Another matter of interest is that *Heligmope postulatus* (Bartrum) seems to have an ancestor in New Zealand in *Lippistes pehuensis* Marwick (*Trans. N.Z. Inst.*, vol. 56, p. 319; Pl. 73, Figs. 6, 8, 1926). This has the same sculpture and basal sinus, but the spire is so much lower as to be sunk below the body whorl, so that the shape of *Lippistes* is simulated. I have previously (*Trans. N.Z. Inst.*, vol. 57, p. 396, 1926) placed this species with the Recent *benhami* in *Zelippistes*, but Dr. Marwick has pointed out to me that relationship is rather with *postulatus;* I have since seen the unique holotype and quite agree. It comes from the Geological Survey locality 1144, Okoke Road, 60 chains west of Pehu Trig., in the upper Waitara Survey District. Grange (*N.Z.G.S. Bull. No. 31*, N.S., p. 37, 1927) places this locality in the Urenui beds about 300-700 ft. above the base; the Urenui and Tongaporutu beds he includes (*l.c.*, p. 39) in a new stage, the Taranakian, between Awamoan (Lower Miocene) and Waitotaran (Lower Pliocene). *Heligmope pehuensis* (Marwick) seems, therefore, to be Upper Miocene, and ancestral to the Waitotaran *H. postulatus*. If this is so, and *Heligmope* does not turn up in pre-Kalimnan beds

in Australia, one would be justified in believing that this peculiar genus, if it did not originate in New Zealand, at least occurred here before it reached Australia. No records of *Heligmope* have been made by Chapman in his examination of the Mallee (*Rec. Geol. Surv. Vict.*, vol. 3, pt. 4, 1916), Sorrento (*idem*, vol. 5, pt. 1, 1928) and other bores, which passed through Janjukian-Kalimnan strata in many different localities and conditions.

A final suggestion may be made regarding the correlative uses of this valuable genus. Marwick, in discussing the correlation of strata on opposite sides of the Tasman Sea (*Austr. Assoc. Adv. Sci.*, vol. 17, p. 47, 1926) has remarked that, "In conclusion, it may be stated that the only exact correlation which is backed by adequate palaeontological evidence, and which stands unchallenged is that of the Lancefieldian and Castlemainian zones of the Lower Ordovician," while in an earlier account (*l.c.*, vol. 16, p. 330, 1924) he stated that, "Of the twenty-five species (of mollusca) reviewed, specific identity of the Australian and New Zealand shells can be upheld in only one instance. . . . In correlating Australasian Tertiary strata the stratigrapher will therefore have to deal with generic correspondence and specific resemblances rather than with specific identities." This makes it extremely difficult to correlate any two such horizons with any degree of exactitude, especially in the upper Miocene and late Pliocene. Unless some sort of connection existed by means of which a group of short-lived genera could cross and be found living (and therefore fossil) simultaneously in the two countries, it might be deceptive to rely even on generic correspondence. And, for reasons already given when discussing the genus *Natica*, I am doubtful whether much reliance can be placed on many of the specific resemblances either. But in the special case of *Heligmope* we have a very short-lived genus existing not in either country, but on the ocean surface between them. Therefore, as its species evolved, it is reasonable to assume that they would be washed up on the shores of each country simultaneously, and thus when found as fossils provide a fairly reliable index of age equality. Is it, then, too much to postulate that this "*Turbo postulatus*" allows us to fix a Lower Pliocene base-line from which the correlations of higher and lower beds on either side of the Tasman may be surveyed? I suggest that the Kalimnan horizon in Australia (or that part of it which contains *H. dennanti*, should it ultimately be subdivided) and the Waitotaran stage in New Zealand are exact equivalents, and invite criticism to confirm or disprove this. Not a single species is known to me to be common to the two stages, so that in doing this I am placing complete reliance on the similarity between *Heligmope postulatus* (Bartrum) and *H. dennanti* Tate; the slight differences to which I have drawn attention appear to me to be no greater than those found at the present time between specimens of *Ianthina ianthina* from the shores of New Zealand, Australia, and the Kermadec Islands.

On *Austrosassia, Austroharpa,* and *Austrolithes,* New Genera; with some Remarks on the Gasteropod Protoconch.

By H. J. FINLAY, D.Sc.

[*Issued separately, 23rd May, 1931.*]

Genus **Austrosassia** nov.

Type: *Septa parkinsonia* Perry, 1811.

I PROPOSE to replace the use of *Austrotriton* Cossmann in New Zealand by the above name.

Iredale (*Trans. N.Z. Inst.*, vol. 47, p. 459; 1915) applied *Austrotriton* to the Recent *parkinsonia* Perry, stating that it " stands quite alone when compared with the other Recent species, so that I make use of the generic fossil name, basing its use upon Kesteven's studies." Later (*Proc. Linn. Soc. N.S.W.*, vol. 49, pt. 3, p. 253; 1924) he re-affirmed this location, and on the strength of this I have used *Austrotriton* for a number of New Zealand Tertiary species (*Trans. N.Z. Inst.*, vol. 55, pp. 453-455; 1924). All this depends in the first instance on Kesteven's remark (*Proc. Linn. Soc. N.S.W.*, vol. 27, p. 454; 1902), "*L. parkinsonianum* is the recent representative of *L. radiale, abbotti, textile, woodsi,* and *tortirostris.* This group is more distinct than any I have studied." Later (*l.c.*, vol. 37, p. 49; Pl. 1; 1912) he again discussed and figured *parkinsonianum, tortirostris,* and *abbotti* to show their intimate relationship.

Undoubtedly the last three species are related, but I think Kesteven's earlier "*parkinsonianum*-group" was a heterogeneous assemblage. The shell habit in all is somewhat similar, but the protoconchs of, say, *woodsi* and *tortirostris* are in my opinion fundamentally distinct. I think the only satisfactory basis for the classification of the Cymatiidae is the protoconch, and would reject a species from any of the shell groups if it does not agree with the other members in apex. This is in direct opposition to Kesteven's opinion (*l.c.*, vol. 27, p. 470), " If the group is to be split up into various genera it will be impossible to disregard the form of the apices, now that we know so much about them; and we shall have such dissimilar species as *L. costatum* Born, and *L. cornutum* Perry, in the same genus, and species so absolutely alike as *L. tortirostris* and *L. radiale* in different genera. Considered as varieties of one type, they may, for the convenience of the monographer, be disregarded." Emphatically no!—that is fatally easy, but unscientific. Reduction of this dictum to its essentials would end in classifying all gasteropods as varieties of one type. Kesteven's own results sufficiently attest the uselessness of this method; using it, he ended up by classing all the Tritons in one genus!

I would distinguish at least three general types of protoconch in this Family:—

(A) Tall, narrowly conical, pointed, of about 4 whorls, set slightly oblique to the axis of the shell, entirely coated with a persistent brown horny envelope, strikingly differentiated in colour from the rest of the shell, *e.g.*, *Lampusia pilearis* (Linn.). This is the same kind of apex as possessed by *Harpa, Neothais, Janthina,* and, in a wider and lower form, by *Tonna* and *Cassis,* and is very common among tropical molluscs. It almost certainly represents a Sinusigera, free-swimming embryo, such as Iredale has commented on (*Proc. Mal. Soc.*, vol. 9, pt. 5, pp. 319-323; 1911). I endorse his dictum that "no species should be allotted to a group of which the type has been shown to possess a *Sinusigera* apex, unless it also possesses such an apex."

(B) Similarly polygyrate, but turbinate, with globose rapidly increasing whorls, usually wider than high, the tip minute and planorbid; set almost symmetrically on shell, polished, white, and shining, with no trace of a horny envelope, differentiated from normal shell only by inception of adult sculpture; in the Cymatiidae most examples of this type of apex also have a few distant linear spiral ridges on its lower whorls, *e.g.*, *Fusitriton kampylum* (Watson), *Cymatiella quoyi* (Reeve), *Austrosassia parkinsonia* (Perry), etc. This is the type seen in *Pseudotoma* in the Turridae, and in *Voluta, Yetus, Aulica,* etc., in the Volutidae.

(C) Paucispiral, of about two whorls, the last normal and much as in B, but the initial whorl quite irregular in shape, roughened, and markedly differentiated in texture from the polished succeeding whorl, beginning in a lateral blob or point which may be quite erect and sharp; the whole appearance is that of a scar left by the loss of some integral part. The conspicuous differences between this style of apex and the previous one are well illustrated by Harris (*Cat. Tert. Moll. B.M.*, pt. 1; Pl. 6, Figs. 6 and 7; 1897) in his figures of the embryos of *radialis* and *annectans* Tate. This is the Scaphelloid, or in some cases even Caricelloid apex so common in the Volutidae; it is absolutely the apex of *Voluta junonia,* the type of *Scaphella,* but is not the type seen in *undulata,* which has been often quoted as the genotype. The scar seems to denote the loss of a previous entirely horny part, which did not envelope the whole embryo, calcification proceeding before this was completed. This type seems to be absent in Recent Cymatiidae, but was characteristic of the Australian Balcombian group to which the name *Austrotriton* Cossmann should be applied.

There is a fourth type of apex, which I have not observed in the Cymatiidae, but which is common in other Families:—

(D) Paucispiral, of 1½-2 whorls, rounded and globose, generally quite small but occasionally large, everywhere smooth and polished, generally marked off from adult whorls by a distinct varix, but otherwise not differing anywhere in texture or material from the normal conch, the initial whorl rather bulbous and asymmetrically placed; nowhere horny. This is the simplest type of apex, the true Fusid

one as seen in *Colus, Cominella,* etc., and, in a modified taller form, in many genera of the Cancellariidae and Pyrenidae.

Evolution must proceed in the apex as well as in the shell, and as a working basis I suggest that the course normally followed is from Paucispiral calcareous (D)—Polygyrate calcareous (B)—Paucispiral part calcareous and part horny (C)—Polygyrate horny (A). The horny parts may and mostly do have a limy stratum underneath, but this when exposed lacks the regularity and polish of the normal shelly and horny surfaces. Dall (*Tert. Fauna Florida,* pt. 1, p. 66; August, 1890) remarks as regards the Volutidae, " There are several forms of the shelly nucleus. It undoubtedly preceded the horny one in this group."

According to this theory, *Lampusia* is more advanced in development than *Austrotriton,* which in turn has gone further than *Austrosassia,* while the simplest type from which this evolved is not known to us (perhaps a Muricoid genus). The geological age of these genera seems to support this; *Lampusia* being a Recent development, probably not antedating the Pliocene, *Austrotriton* being an Oligocene-Lower Pliocene genus, and *Austrosassia* dating back at least to the Eocene, but like many primitive lines, surviving even yet. It is but just, however, to note that arguments based on the geological age of lineages are always liable to be upset by new discoveries, so that this remains a pure hypothesis.

This apical classification is of course not laid down as a primary division, for it would be absurd to say that all species which agreed in type of apex were congeneric. But I would definitely say that species which do not agree in type of apex cannot be congeneric. There are the nervous system, radula, operculum, and shell formation also to be taken into account, and exactly the same remarks apply to these. Which one of these is of prime importance must depend on circumstances; no hard and fast rules seem definable. Thus we must inevitably get a large number of genera based on different combinations of these five main variables; as in mathematics, if any four of these remain constant and the fifth varies, no equation results, and a distinct group ought to be recognised.

To return to *Austrotriton*: Cossmann proposed this name (*Ess. Pal. Comp.,* livr. 5, p. 98; Dec., 1893) chiefly on variation from the normal in shell features; he figured the apex (type C) of *cyphus* Tate, but did not realise its importance, as he included in the genus *abbotti* Ten.-Woods, which has a type B apex.

Kesteven figured the apices of nearly all the Australian Tertiary species, but also did not realise their evolutionary importance, and, regarding them " as varieties of one type," lumped every species in one genus *Lotorium.* His figures, especially of the polygyrate apices, do not show well the essentially different appearance of type A from type B. *Triton woodsi* Tate has the most typical Caricelloid apex (type C), but is closely simulated by *radialis* and *gibbum,* while *armatum, cyphum, protensum,* and *tumulosum,* all of Tate, have a lateral beginning, not raised into a spike, but still absolutely of type C. On the other hand, *tortirostre* and *crassicostata* Tate, and *abbotti* T.-W. have a well-formed type B apex, and are, as Kesteven noted,

the real relatives of *parkinsonia* Perry. *Annectans* Tate I have not seen, but if the specimen Harris figured was correctly identified, it belongs to this latter group. All the New Zealand Tertiary species whose apices have been seen also have this type.

Since Cossmann definitely named *Triton radialis* Tate as type of *Austrotriton,* there is no alternative but to apply it to the type C group. A new name is therefore needed for the New Zealand and other type B species, and I therefore propose *Austrosassia* as above. It is with some hesitation that I separate this group from *Sassia* Bellardi, 1871 (Genotype: *Triton apenninicum* Sassi; a Pliocene species), which apparently has the same apex. Cossmann (*l.c.*) records species of this genus from Palaeocene to Recent, and placed therein *tortirostris, annectans, tumulosus, protensus, oligostirus,* and *gemmulatus,* all of Tate, an apically heterogeneous series. Kesteven (*l.c.*, p. 472) stated that *apenninicum* "might, judging by Hoernes and Auinger's figures, be included in my *quoyi*-group." Cossmann's figure supports this suggestion, and he gave *quoyi, eburneus,* and *verrucosus* Reeve as the Recent representatives of the genus. These are all members of Iredale's genus *Cymatiella* (*Proc. Linn. Soc. N.S.W.*, vol. 49, pt. 3, p. 254; Oct. 24, 1924), typified by *quoyi* Rve. *Sassia* does not quite agree in shell habit with the Austral *Cymatiella* series, or with *Austrosassia,* so the three names are best treated as distinct until more is known of the lineage in Europe.

Austrosassia procera nom nov.

I propose this to replace *Triton minimus* Hutton, 1873 (*Cat. Tert. Moll.*, p. 5), *non Triton minimus* Giebel, 1847 (*Fauna d. Vorwelt,* vol. 1, pt. 2, p. 188). I have described and figured the unique holotype (*Trans. N.Z. Inst.*, vol. 55, p. 454; Pl. 48, Fig. 5), from Broken River, Trelissick Basin, and named the common Awamoan and Hutchinsonian New Zealand form *Austrotriton maorium;* this is very close to *parkinsonia. Insignitum, cyphoides,* and *decagonia* Finlay also all have this style of apex and shell, and may be referred to *Austrosassia.*

Austrosassia reticulata (Suter).

1917. *Streptosiphon* (*Streptopelma*) *reticulatum* Suter, *N.Z. Geol. Surv. Pal. Bull. No. 5,* p. 17; Pl. 11, Fig. 25. Waihao River.

1924. *Cymatium marwicki* Finlay, *Trans. N.Z. Inst.*, vol. 55, p. 456; Pl. 51, Figs. 1a, 1b. McCulloughs Bridge.

These two specimens were described from the same locality, and I have no doubt that they represent the same species. Suter's description of the columella as having "a distinct oblique fold at the deflection towards the canal, and two smaller folds higher up" at first sight does not correspond well with my description of the columella as "straight, with five plaits on lower part, and a few rugosities above these." But I have since observed that my *Cymatium decagonium* (*l.c.*, p. 460; Pl. 48, Fig. 4) and the specimen described below both show two obsolete pillar plaits far within the aperture. These are not strong as in *Semitriton,* but like the rudimentary plaits

seen in some Recent species such as *lotorium* and *femorale.* I do not doubt that these same plaits exist in *marwicki,* and were either overlooked or are covered with matrix; every other detail of figure and description corresponds so well that the synonymy seems certain.

A. maorium has nearly always only two strong elongated tubercles at the base of the pillar, one of them marking the twist; rarely there are a few denticles above these, but none below and no internal plaits. *A. reticulata,* and *decagonia* have two ridge-like tubercles, three denticles decreasing in strength below these, a few rugosities due to the basal spirals above them, and two (or perhaps more) low internal plaits. But as these details are more or less distinctly shown by *tortirostris* Tate, and the shells are otherwise so similar, separation does not seem justified. The pillar plaits of *Semitriton* are quite different.

A. reticulata is the direct descendant of *decagonia* Finlay, though this was not noticed by me at the time of description. Additional specimens of each have since been collected, and demonstrate this fact; a perfect shell from McCulloughs Bridge differs in a few respects from the type, being more nodular, and having a strong keel; it is here described by comparison with *decagonia* to show the close alliance between these two:—

Shell directly descended from *decagonia* Finlay, but more slender. Apex of four convex whorls, early ones flat, tip planorbid and minute, later ones globose and inflated, with four linear distant spiral ridges, merging without varix into adult sculpture. Spirals same in number and arrangement as in *decagonia,* but coarser, wider, and blunter, the interstitial riblets almost filling up the spaces instead of linear and distant. Axials same in number, but much stronger and closer together, 1½-2 times their width apart instead of 3-4. (Additional specimens of *decagonia* show that the axials are usually closer together than in the type; there are normally 7 intervariceal ribs, but another weak one may occur just before a varix). Tubercles considerably larger and more prominent. Aperture exactly as in *decagonia.*

Height, 27 mm.; width, 13 mm.; height of spire, 13.5 mm.

Genus **Austroharpa** nov.

Type: *Harpa pulligera* Tate, 1889.

Tate (*Trans. Roy. Soc. S.A.,* vol. 11, pp. 149-152; April, 1889) described eight Australian Tertiary species of *Harpa; lamellifera, sulcosa, spirata, cassinoides, abbreviata, tenus, pulligera,* and *clathrata,* and later (*Proc. Roy. Soc. N.S.W.,* vol. 27, p. 173; 1894) named another one, *pachycheila,* noting in this case that it belonged to the Section *Eocithara.* In 1896, Verco described (*Trans. Roy. Soc. S.A.,* vol. 20, p. 218) a new Recent species of *Harpa* from South Australia as *H. punctata,* noting that "the two other Australian forms, *H. ventricosa* Lamk. and *H. minor* Lamk., are inhabitants of the warmer regions of the North and North-West parts of the continent." In April 1899, Cossmann (*Ess. Pal. Comp.,* livr. 3, p. 76) referred *sulcosa, lamellifera, pachycheila, spirata,* and *tenuis* to *Eocithara,* mentioning no Australian forms under *Harpa* s. str. Finally, Verco

in 1913 (*Trans. Roy. Soc. S.A.*, vol. 37, p. 446) compared his *punctata* with the Tertiary species, examined all the types of these, and referred every one to *Eocithara*, regarding *punctata* as the only survivor of this otherwise extinct section. He quoted the differential characters of the section given by Cossmann, whose final words in this respect were, "Finally the riblets are more completely folded upon the suture, and cover it, joining one another, though this last character is less visible in the South Australian *Eocithara*, which have besides a more globular protoconch."

This is the only hint given of a fundamental distinction from both *Harpa* and *Eocithara* shown by several of the Australian Balcombian species. True *Harpa* has the same apex as described under *Austrosassia*, type A; this again seems to be a comparatively recent evolution, restricted to warm seas. Cossmann quotes one species from the Oligocene, and one from the Miocene, but these are almost certainly not true *Harpa*; his Miocene species is quite certainly not, for his description of the protoconch of the genus, based on it, is "lisse, petite, globuleuse, à nucléus planorbulaire." At the same time (*l.c.*, p. 75) he described and figured the apex of *Eocithara mutica* (Lamk.), the genotype, as "lisse, globuleuse, composée de trois tours, à nucléus déprimé et obtus"; this is a type B protoconch, and would alone separate *Eocithara* from *Harpa*. Of all the Australian forms only one, *H. lamellifera* Tate, has this apex; it is large and turbinate, of nearly three (not two, as given by Tate) smooth, slightly shining, very convex whorls, rapidly increasing in width, and separated by canaliculate sutures, the tip somewhat prominent and globular, slightly inturned. Harris (*Cat. Tert. Moll. B.M.*, pt. 1, p. 79; Pl. 4, Figs. 3a, 3b; 1897) gives a good figure of it and remarks that "Compared with the protoconch of . . . . *H. mutica* Lk. . . . it is relatively much larger and is more depressed though of the same general character."

H. pachycheila; and perhaps *cassinoides* Tate (which I have not seen), would, if belonging to this group, have apices referable to a variety of type D, of about two smooth and shining shelly whorls, the first very inflated, upturned, and somewhat immersed (compare this with the apex of *Hypocassis* Iredale, later described). But I suggest that these two species would be better referred to Family Cassididae, perhaps as *Oniscidia*.

Nearly all the remaining species have an apex quite different in character from *Harpa* and *Eocithara*. It consists of a well defined last volution, of not quite one whorl in extent, distinctly but not prominently marked off from adult sculpture, narrow, very lightly convex, smooth and shining, sides almost perpendicular; surmounted by an initial whorl in the form of a more or less inflated dome-shaped blob, of indefinite coiling, roughened and pitted, appearing like the top of an egg, most of which is immersed in the succeeding whorl, from which it is distinctly marked off by a very oblique dividing line in good specimens. It is exactly like the apex of *Pterospira* Harris in the Voutidae, with the initial egg-whorl more immersed. Tate's original figure of *pulligera* (*Trans. Roy. Soc. S.A.*, vol. 11; Pl. 6, Fig. 9; 1889) and Harris's good figures of the protoconchs of *tenuis* and

abbreviata (*Cat. Tert. Moll. B.M.*, pt. 1; Pl. 4, Figs. 4, 5) give a clear idea of the formation of this peculiar embryo.

It will at once be seen that this is a type C apex, quite comparable in general style to that of *Austrotriton*, though different in detail. Of the Balcombian species, *pulligera*, *sulcosa*, *abbreviata*, *tenuis*, and the Recent *punctata* certainly possess it, *spirata* probably has it, while *clathrata* I have not seen.

My arrangement, then, of the Australian Harpidae would be as follows:—

Genus *Harpa* Pallas, 1774. (*Spic. Zool.*, vol. 10, p. 33).

Genotype (by tautonymy): *Buccinum harpa* Linn.

Harpa Humphrey, 1797; *Mus. Calonn.*, p. 18.
Harpa Bolten, 1798; *Mus. Bolten*, vol. 2, p. 149.
Harpa Lamarck, 1799; *Mem. Soc. H.N. Paris*, p. 71.
Harpalis Link, 1807; *Beschr. Nat. Samml. Univ. Rostock*, vol. 3, p. 114.
Harparia Rafinesque, 1815; *Analyse de la Nat.*, p. 145.

1. *Buccinum harpa* Linn., 1758; *Syst. Nat.*, ed. 10, p. 738: ed. 12, p. 1201, 1767.
(= *major* Bolten, 1798, = *ventricosa* Reeve, 1843).

(Hedley, in his Queensland list, also included, probably on Melvill's authority, *H. amouretta* Bolten, 1798 = *minor* Lamk., 1822, but Iredale in *Mem. Queensland Mus.*, vol. 9, pt. 3, p. 283, June 29, 1929, has discussed the matter, and there makes the "first authentic record" for North Australia, a juvenile of *harpa* Linné).

Genus *Eocithara* Fischer, 1883. *Man. Conch.*, p. 601).

Genotype (by original designation): *Harpa mutica* Lamk.

3. *Harpa lamellifera* Tate, 1889; *T.R.S.S.A.*, vol. 11, p. 149; Pl. 6, Fig. 2.

Genus *Austroharpa* Finlay, n. gen.

Genotype: *Harpa pulligera* Tate.

4. *Harpa punctata* Verco, 1896; *T.R.S.S.A.*, vol. 20, p. 218; Pl. 6, Figs. 3, 3a, b.
5. *Harpa spirata* Tate, 1889; *Id.*, vol. 11, p. 150; Pl. 6, Fig. 3.
6. *Harpa abbreviata* Tate, 1889; *l.c.*, Pl. 6, Fig. 7.
7. *Harpa sulcosa* Tate, 1889; *l.c.*, Pl. 6, Fig. 10.
8. *Harpa tenuis* Tate, 1889; *l.c.*, p. 151; Pl. 6, Fig. 1.
9. *Harpa pulligera* Tate, 1889; *l.c.*, Pl. 6, Fig. 9.
10. (?) *Harpa clathrata* Tate, 1889; *l.c.*, Pl. 6, Fig. 8.
11. *Austroharpa tatei* Finlay, n. sp. (described below).

The other genera of the Family belong to the Cryptochordinae, and do not occur in Australia. They are as follows: *Cryptochorda* Moerch, 1858 (genotype: *Buccinum stromboides* Herman.; Eocene), *Silia* Mayer-Eymar, 1877 (*Umgeg. von Einsiedeln*, p. 59, genotype:

Silia zitteli M.-E., n. sp.; Eocene—Dall says this is known only from an internal cast), *Lyrianella* Nelson, 1925 (*Bull. Dept. Geol. Sci., Univ. Cal. Pub.*, vol. 15, No. 11, p. 432, genotype: *Cryptochorda lyrata* Nelson, n. sp.; Eocene), and *Tritonoharpa* Dall, 1908 (*Bull. Mus. Comp. Zool.*, vol. 43, No. 6, p. 319, genotype: *T. vexillata* Dall, n. sp.; Recent).

One may note in conclusion that Cossmann and Pissaro (*Mem. Geol. Surv. India*, Pal. Indica, N.S., vol. 3, Mem. 1, p. 22; 1909) described a *Harpa morgani* of which Vredenburg remarks (*l.c.*, vol. 10, Mem. 4, p. 35; 1925), "In Cossmann and Pissarro's memoir this species has been compared also with *Harpa jacksonensis* G. Harris from the Upper Eocene of Mississippi, and with the numerous fossil species from the Australian Tertiary. The latter are stated to differ on account of their more numerous or more overlapping lamellae. This difference does not apply in the case of *Harpa cassinoides* Tate from the Murray Desert, which however is readily distinguished by its much more ventricose shape." But as elsewhere on the same page Vredenburg remarks that *morgani* is hardly separable varietally from *Harpa mutica* Lk., and describes the same sort of protoconch for it, it is evident that this Indian *Eocithara* is not comparable with the Australian *Austroharpa*. An Oligocene species described later by Vredenburg (*Mem. Geol. Surv. India*, vol. 50, pt. 1, p. 122; 1925) as *Harpa* (*Eocithara*) *narica* is still an *Eocithara*, and Vredenburg says of it, "In several respects the Nari shell (*narica*) seems somewhat intermediate between *Harpa morgani* and the living *Harpa conoidalis* Lamk., of which it perhaps represents an ancestral form."

Austroharpa tatei n. sp.

Extremely close to *sulcosa* Tate, and evidently derived from it. Somewhat smaller and more solid. Apex exactly same type but smaller. Shoulder of whorls flat, not concave as in *sulcosa*, the bordering angle not sharply ridged, but bluntly rounded. Three broad low spiral bands on spire whorls and 10 on body whorl, as against 4 and 14 respectively in *sulcosa;* interstices but little narrower than ribs instead of considerably narrower. Thirty-three narrow crisp axial lamellae over-riding spirals on body whorl, as against 45; not projecting as lamellose hollow points on shoulder keel. Fasciole with the S-shaped lamellae less prominent on the ridge, more prominent in the umbilical excavation. Aperture narrower.

Height, 25.5 mm.; width, 17 mm.

Locality—400-500 ft., Abbatoirs Bore, Adelaide, South Australia ("Older Pliocene").

Type in Finlay collection.

Genus **Austrolithes** nov.

Type: *Fusus bulbodes* Tate, 1888 (as restricted by Pritchard).

Pritchard (*Proc. Roy. Soc. Vict.*, vol. 17, pp. 320-324; Sept., 1904) showed that Tate confused two species when he described his *Fusus bulbodes* (*Trans. Roy. Soc. S.A.*, vol. 10, p. 139; Pl. 7, Fig. 8; 1888). He separated these as *Clavella bulbodes* (Tate), typical,

common at Balcomb Bay, and widespread in the Balcombian, and *C. platystropha* sp. nov. from Muddy Creek lower beds. The latter he remarked was " very much more of the type of *C. longaevus* than any other described Australian species." Tate (*l.c.*, p. 141) also remarked of *Fusus tateanus* T.-W. that it was " remotely related to *F. longaevus* of the European Eocene." One other species, *Fusus incompositus* Tate (*l.c.*, p. 137; Pl. 3, Fig. 9) is generally referred to *Clavella* or *Clavilithes* by Australian conchologists.

The remarkable series of Eocene shells classed as *Clavella* s. 1, in older literature has been ably discussed by Grabau (*Phylog. of Fusus,* pp. 98-144, 1904). He has divided this series into four main groups, *Clavilithes* typical, *Clavellofusus, Rhopalithes,* and *Cosmolithes.* The last three have tiny protoconchs, and the latter two have plicate columellas.

The Australian species show a superficial likeness to these " phylogerontic Fusidae," but even in conch characters are not quite the same as the English and Paris Basin shells. The sutural shoulder, so strongly developed on the later whorls of the European forms is absent, the whorls clasping each other much more tightly; the basal angulation is more rounded and much less conspicuous; and the pillar is long and very regularly decreasing, without a strong twist at the beginning of the canal as in true *Clavilithes.* But apart altogether from these differences, the character of the protoconch renders separation imperative. The only genus we need consider in this respect is *Clavilithes* itself; Grabau says of it (*l.c.*, p. 104), " The protoconch of this genus is very striking and is distinctive. . . . The first whorl is depressed and naticoid, with a minute apical portion. The whorl gradually enlarges, but after the first volution the proportional increase in size is much less, so that the whorls produce a nearly cylindrical protoconch. There are from two and a half to four whorls thus giving the protoconch a distinctively papillose appearance." The British species have, according to Grabau, uniformly a slightly different apex from the Parisian ones; the apex of *deformis* Solander he describes thus (*l.c.*, p. 120): " The protoconch is much larger and more robust than is even the case in the French specimens of the genus. Its median whorl has a diameter of nearly 4.5 mm., while the average diameter of the median whorls in the French species is less than 3 mm., seldom exceeding 2.5 mm. In one specimen from Barton the diameter of the median whorl was found to be 5 mm. . . . The number of volutions varies from three to nearly four, and they almost always show an irregularity in thickness. A characteristic feature not found in the French species is the flattening of the upper exposed portion of the protoconch, thus giving a sloping or trochiform character to the apex. The apex of the protoconch of the Parisian species is naticoid with the convexity of the whorl unimpared."

Compare with this the description of the apex of *Fusus bulbodes;* Tate says " terminating in a large ovoid summit," while Pritchard notes the "remarkably large mammillate embryo." This inadequately describes the most curious feature of this species; Tate's figure shows it moderately well, but all Pritchard's figured shells are decollate. The apex is really of about two whorls, the second quite narrow, with

straight sides, a trifle angulated near lower suture, somewhat shining, and towards its close with gradually more distinct spiral scratches which become the grooves of the normal whorls, merging imperceptibly into the adult conch; the first whorl relatively enormous, egg-shaped, well separated from the second whorl by a change in texture and irregularity in suture line, running in same spiral as second whorl for but a short distance, then suddenly rising erect and expanding into a large bulb, which curves over and has its nucleus immersed in its own volution and that of the second whorl, the whole surface coarse, chalky, and pitted; the bulb measures 5 mm. across and nearly 6 mm. high. This is exactly the embryo of the Volutid genus *Pterospira* Harris, except that it is smaller and has the nucleus totally immersed and hidden instead of lateral.

Here again, then, is a kind of type C apex, but the initial horny-covered stage entirely dwarfs the remaining normally calcareous volution. Still, there is no apical difference further than relative size of the two whorls between *Austrotriton, Austroharpa, Austrolithes*, and *Pterospira;* a regular and most interesting gradation is shown in the comparative size of the " blob " in these four genera.

The protoconch of *Clavilithes* is truly Scaphelloid, being quite like that of *Amoria* Gray in the English forms, or some species of *Alcithoe* in the case of the Parisian ones. It is, therefore, also a type C, but is so different in shape and formation from that of *bulbodes*, that close connection seems improbable. Here, then, is a case of two genera of a group having apices of the same type but of quite different formation, which is probably intimately connected with ovicapsular conditions.

Perhaps there are two series in Australia; no apex of *platystrophus* or *tateanus* has been recorded, and my specimens lack it; *incomposita* (in my only specimen from Aldinga) has a smaller embryo with more than a whorl of rough texture before the nucleus is immersed. It may be a true *Clavilithes*, but till more material is examined is best referred with the other species to *Austrolithes*.

Grabau has explained that the correct name of the genotype of *Clavilithes* Swainson, 1840 (*Treat. Mal.*, pp. 90, 304) (= *Clavella* Swainson, 1835; *non* Oken, 1815) is *Fusus* (*Cyrtulus*) *parisiensis* Mayer-Eymar, *Fusus longaevus* Lamk., 1803 (for which Swainson instituted the genus) being preoccupied by Solander in 1766.

Family STRUTHIOLARIIDAE.

This exhibits another case of very similar shells with fundamentally different embryos. Here, however, only two types have been observed. *Monolaria* Marwick, *Struthiolaria* Lamk., and *Callusaria* Finlay have a 2½-whorled regularly coiled shelly almost planorbid nucleus, the tip minute and symmetrical—this may be referred to type B. *Pelicaria* Gray, on the other hand, has the regular diminution of the apical adult whorls suddenly interrupted by an irregular roughened blob of shelly material, which is quite Scaphelloid in character, and was evidently deposited inside a horny coating. The Australian *Tylospira* Harris at first sight appears related to *Struthio-*

laria in its nodose ornament, but the apex (as seen in some juveniles of *scutulata* dredged in 6-12 fathoms, Twofold Bay, N.S.W) is exactly like that of *Pelicaria*, only considerably smaller. On inspection, it is also seen that the ornament of *Tylospira* is really more similar in style to *Pelicaria* than to *Struthiolaria*, so that a close alliance between the two former genera is indicated. The earliest *Pelicaria* so far known is *Struthiolaria nana* Marwick, 1926 (*Trans. N.Z. Inst.*, vol. 56, p. 318, pl. 73, Fig. 4) from Tirangi Stream, a Taranakian horizon, while the oldest *Pelicaria* is probably the new species described below from the "Older Pliocene" of the Adelaide basin. These two deposits are probably approximately equivalent in age, though there is no resemblance between *nana* and *marwicki*. This is interesting and suggestive in view of the hypothesis advanced by me in another paper in this volume ("On *Turbo postulatus* Bartrum, etc.").

This *Pelicaria* -*Tylospira* apex is probably a variety of type C. After the initial rough blob, fine spiral sculpture starts immediately, and if there is another whorl to the protoconch, as in typical type C, it is ornamented precisely as the normal conch, grades into it, and cannot be detected. But as there is probably all gradation in apices of this kind from those entirely coated with chitin to those which have a subsequent shelly portion, I include under type C at present all those embryos generally known as *Scaphella*, *Caricella*, or *Cymba* nuclei. Three very tiny apical fragments of *T. scutulata* in quite fresh condition, from 6-12 fathoms Twofold Bay, N.S.W. presented exactly the same condition as New Zealand Recent and Tertiary species of *Pelicaria*, the blob being the same colour as the rest of the shell and showing no trace of horny matter; its rough surface, however, almost certainly indicates the previous presence of such a coating, lost while still in the ovicapsule, as in *Aurinia* and other Volutidae.

Pelicaria marwicki n. sp.

Shell closer to *coronata* Tate than to *clathrata* Tate, but, like these two, much shorter in the spire and with a more thickened aperture than the Recent *scutulata* Mart. It has the short spire of *clathrata*, but no lamelliform axials; whorls angled, and growth lines and outer lip far more sigmoid. Related to *coronata* in general habit of shell and callus deposit (which extends over whole of body whorl, and sometimes ¼ of next whorl; *clathrata* has only two-thirds of a whorl callused over) and the tendency to sulcation of the suture anteriorly, but this never goes to the same depth and extent, the callus shoulder remaining mostly as a flat or lightly concave platform. Shell more squat than *coronata*, spire being lower than aperture; angle of whorls much less developed and lower down, almost entirely hidden by callus on penultimate whorl. Peripheral knobs about the same in number, but very much weaker; small sharp tubercles instead of projecting nodules. Apertural callus very heavy, forming three marked "lips," one projecting upwards and outwards at suture, another forming a pad on base, a third at end of the strongly marked fasciole. Columella very much bent (almost a semicircle) to the right.

Height, 38 mm.; diameter, 31.5 mm.

Locality—400-500 ft., Abbatoirs Bore, Adelaide, South Australia ("Older Pliocene" of Tate) eight shells.

Type in Finlay collection.

This is probably ancestral to both *clathrata* and *coronata*, which are from the Gippsland coast Kalimnan beds, and, through *coronata*, to *scutulata* Martyn.

The significance of these and other types of gasteropod protoconch remains to be demonstrated by biological research. Some of the questions that need investigation are:—

(1.) What is the reason for the change from shelly to horny embryo, and can any artificial conditions bring it about?

(2.) Why are the horny types apparently more advanced, and in general more characteristic of later geological epochs?

(3.) Why are the type A apices practically confined to tropical and sub-tropical seas and so abundant there, while the much older type C embryos are more widely spread? Did the horny type of apex evolve on account of tropical conditions?

(4.) Is the type A apex a further evolution from type C or is it very distinct? Why is the chitin so persistent in it and so easily and early lost in type C.

(5.) What is the significance of the change from paucispiral type D to polygyrate type B in the shelly series, and from paucispiral type C to polygyrate type A in the horny series? Do these different embryos show any notable difference in swimming powers, and hence distribution?

(6.) Is there any relation between the fecundity, stability, and adaptability of the species and its type of embryo?

These are questions highly interesting from a systematic and evolutionary point of view. Dall has fairly fully discussed the appearance and types of horny apex in the Volutidae, but the matter has not gone much further. I now suggest that the Scaphelloid and pseudo-Scaphelloid apex is more common in the mollusca than was previously thought. In the present paper I have shown its existence in *Austrotriton* (Cymatiidae), *Austroharpa* (Harpidae), *Clavilithes* and *Austrolithes* (Colidae) and *Pelicaria* and *Tylospira* (Struthiolariidae), while elsewhere (*Trans. N.Z. Inst.*, vol. 57, p. 414, 1926) I have noted its occurrence in *Glaphyrina* (Fasciolariidae). Finally, comparison may be made with the protoconchs of *Columbarium* von Martens and *Hypocassis* Iredale, where the apex has the same bulbous and irregularly globular first whorl, turned almost at right-angles to the plane of the next, the nucleus immersed; but the embryo is polished and smooth throughout as if there had been no horny envelope. This seems to be a form of the type D apex in which the initial whorl is of irregular growth.

It may be remarked that *Hypocassis* Iredale (*Rec. Austr. Mus.*, vol. 15, No. 5, p. 329, April 6, 1927), which was founded on shell characters and the existence of "a long lineage in the south of Australia" (genotype: *Cassis bicarinata* var. *decresensis* Hedley), is perfectly distinct from *Cassis* in its apex alone. The large wide

polygyrate horn-covered embryo of *Cassis* s.str. (a form of type A with the same shape as type B) is here replaced by a relatively small blunt paucispiral shelly apex, the first whorl distorted and immersed. (Apex described from the Balcombian *Cassis exigua* T.-W., which Iredale says is a fossil representative of *bicarinata*). This is almost identical with the apex of *Columbarium* as seen in the Balcombian *acanthostephes* (Tate).

After a number of years careful examination of gasteropod apices, I am fully satisfied, in spite of what several authors have written, that the protoconch is one of the most valuable criteria for systematic classification. Not only have I never found it to vary *from type* in a homogeneous genus, but I have also found it so generally constant that in my opinion considerable importance must be placed on it in determining lineage relationships. To the palaeontologist it is as important as the radula is to the malacologist, and should be given just as much consideration.

On the Occurrence of *Strebloceras* in New Zealand.

By H. J. Finlay, D.Sc.

[*Issued separately, 23rd May, 1931.*]

The Family Caecidae contains some of the most curious looking mollusca. *Caecum* itself is little like a gasteropod, while *Meioceras, Watsonia, Parastrophia,* etc., exhibit most bizarre tubular shapes. So far, only one member of the Family has been known from New Zealand, *Caecum digitulum* Hedley, 1904, of which *C. suteri* Odhner, 1924, is a synonym. This is a featureless species, consisting merely of a smooth short curved tube, plugged at one end, but I have now to report a much more interesting addition to the Family in New Zealand.

All Caecids begin with a discoidal embryo, which in every genus but one is shed on adolescence, the decollated tube being plugged with a more or less spiked septum. The single exception is the genus *Strebloceras,* which represents a permanent early stage in the development of the group. In it the embryonic planorbid stage is not shed during life, and the tube subsequently twists out of its plane, so that the adult shell resembles a miniature twisted *Lituites.* All the Caecid genera seem to have existed for a long time, for practically all are recorded from the Eocene, and one doubtful species of *Watsonia* from the Palaeocene; nevertheless, *Strebloceras* is probably the ancestral genus from which the others are more or less directly derived. There are but few species of *Strebloceras* described; two from the English Bartonian (Eocene), one from the French Bartonian, one from the Stampien of Etampes (Oligocene), and two Recent species. Thus the discovery of a new species of *Strebloceras* in the Awamoan horizon (Miocene) of New Zealand is of considerable interest.

As there is much disagreement as to the genotype, a review of the literature becomes necessary.

Cossmann (*Ess. Pal. Comp.,* livr. 9, p. 156; 1912) discusses the genus and the three species known to him and remarks, " le génotype —indiqué par Fischer et Tryon—est manifestment inexact, attendu que *C. subannulatum* de Folin, n'a été décrit qu'en 1869, tandis que Carpenter avait déja créé ce Genre en 1858. . . . Dans ces conditions, j'ai institué comme néotype de *Strebloceras* l'autre coquille publiée par Deshayes (C. Edwardsi)." Certainly the statement of Fisher and Tryon needed correction, but Cossmann's own action was illegal, as *edwardsi* is not amongst the species originally included by Carpenter.

Strebloceras was first proposed in the *Proc. Zool. Soc.* (*Lond.*) for 1858, pt. 26, p. 440. No type was named, and only two Eocene new species described, one of which must therefore be taken as type. I cannot find that anyone has made a previous valid designation, so I here nominate Carpenter's " *S. cornuoides* (Brown) n. s.," the first species, as genotype. This was described from the Upper Eocene of Barton and the Oligocene of Hampstead, while *solutum,* the second

species, was from the Oligocene of Hordwell. These two species are both listed, but no genotype named, by R. B. Newton in his *Syst. List Brit. Oligocene and Eocene Moll.*, p. 216, 1891. The quotation of Brown in connection with *cornuoides* refers to his *Illust. Rec. Conch. Gt. Brit.*, ed. 1; Pl. 1, Fig. 49; 1827, where he introduces the generic name *Cornuoides* for two species, *major* and *minor*, which were subsequently identified as the young of other Caecidae. In the remarks on *S. cornuoides*, Carpenter mentions that specimens of it were alluded to by Forbes and Hanley; they, however, merely say (*Hist. Brit. Moll.*, vol. 3, p. 178; 1853) "The genus (*Caecum*) appears to have begun, so far as we yet know, during the Eocene period, since, according to Mr. Searles Wood, a species of it has been found at Hordwell by Mr. Edwards."

Six years after Carpenter's introduction of the genus, Deshayes (*Anim. s. vert., Bass. de Paris*, vol. 2, p. 302; 1864) described two species from the Paris Basin, *Caecum lituus* and *edwardsi*, which have since been referred to *Strebloceras*, though Cossmann has stated (*Ess. Pal. Comp.*, livr. 9, p. 156; 1912) that *lituus* is a Watsonia. Cossmann (*Ann. Soc. R. Mal. Belgique*, vol. 23, fasc. 3, sp. 22-2; 1887) published one more Tertiary species, *C. bezanconi*, from the Bartonian of Mont-Saint-Martin. Since Cossmann makes no reference to Carpenter's two species, but notes that Deshayes sent Carpenter specimens, it seems to me highly probable that *bezanconi* Cossmann and *edwardsi* Desh. may be synonyms of *solutum* Carp. and *cornuoides* Carp., from the same horizons.

The description of two Recent species completes the genus as known up till now. De Folin discovered the first living shells, three specimens from 40 fathoms off the Honolulu reefs; these he described (*Proc. Zool. Soc. Lond.* for 1879, p. 807) as *Strebloceras subannulatum*. From the Bottle and Glass Rocks and Long Bay, Sydney Harbour, Hedley (*Proc. Linn. Soc. N.S.W.*, vol. 29, pt. 1, p. 189; Pl. 8, Figs. 12-14; 1904) obtained the second Recent species, *S. cygnicollis*, which he remarked recalled *Ctiloceras* in its conspicuous ring-varix.

Strebloceras hinemoa n. sp. (Text-Fig. 1).

Shell very small, a simple conical twisted tube, closed posteriorly by the spiral nucleus. The latter is of two whorls, very glossy, planorbid and regularly increasing, not ending in a varix, but marked off by a fine groove from the adult shell, which appears to be fitted into the embryo rather than directly prolonged from it. Tube becoming suddenly a little wider just after leaving embryo, thence regularly slightly expanding to aperture; glossy, but of different texture from embryo, unsculptured except for dense growth lines, quite irregularly one or two of these may be more prominent, and form a minute groove. Tube slightly bisinuous; if the embryo is placed in a horizontal plane, the tube curves first regularly forwards in this plane as if rapidly uncoiling, then bends downwards at about 30 degrees, then finally while continuing downwards takes a slightly backwards direction. Aperture thin, simple, sharp, circular; decidedly oblique to axis of tube at that point (the inner side of tube projecting fur-

ther), cutting it at about 75 degrees, so that the final plane of aperture is at about 45 degrees to the planes of both the embryo and a vertical section through it.

Length, 2.3 mm.; width of aperture, 0.4 mm.

Locality—Pukeuri, sandy clays in road-cutting (Awamoan), two shells obtained by sieving matrix in water.

Type in Finlay collection.

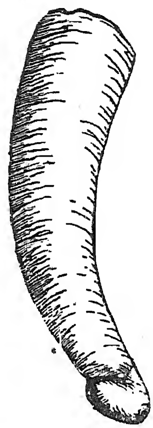


FIG. 1.—*Strebloceras hinemoa* n. sp.: Holotype. × 24.

The Recent *S. subannulatum* de Folin is larger (3 x 0.5 mm.), has a considerably greater twist, enlarges much more rapidly, and is ornamented with regular distant rings. *S. cygnicollis* Hedley is still more unlike, being very slender (3.35 x 0.45 mm.), with strongly marked growth rings anteriorly, aperture nearly at right-angles to plane of embryo, which does not end at the planorbid stage, but continues for some distance as an irregular swollen tube, marked off from the adult shell by a very conspicuous trumpet-like varix. The Tertiary forms, as one might expect, seem nearest to the New Zealand species, and in the absence of good figures, it is difficult to give separative characters, but *solutum* and *bezanconi* seem at once distinct in their long slender shell and minute nucleus. Perhaps *cornuoides* and *edwardsi* are most like *hinemoa,* but they come from lower horizons, and are almost certainly different specifically.

The genus seems to have a most curious distribution in view of the paucity of its species. Perhaps these are not so rare as is thought, but are so minute and fragile as to be easily overlooked, destroyed, or mistaken for true *Caecum*.

I am grateful to Mrs. R. S. Allan for drawing the figure here reproduced.

A Second Species of *Planorbis* from New Zealand.

By H. J. FINLAY, D.Sc. and C. R. LAWS, M.Sc.

[*Issued separately, 23rd May, 1931.*]

THE discovery of another species of *Planorbis* in New Zealand is of more than usual interest. Since *P. corinna* Gray was described in 1850, it has been accepted that there is only one species here, rather widely spread in the North Island, and recorded by Suter also from the River Avon and Lake Wakatipu. We can now announce, however, that there is a second species, apparently restricted to the Hawke's Bay district, differing at sight from *corinna* in its coiling.

Early in 1927, some fresh-water molluscs were forwarded to one of us (Finlay) for determination by Mr. C. S. M. Hopkirk, B.V.Sc., Officer in Charge of the Wallaceville Veterinary Laboratory. The species were rather important, for it was suspected that one of them acted as host for the notorious liver-fluke of sheep. This proved in the end to be *Potamopyrgus zelandiae* Gray, and Mr. Hopkirk has recorded this in the *N.Z. Journal of Agriculture*, vol. 35, No. 3, pp. 175-177; Sept. 20, 1927. He has also shown (*l.c.*, pp. 141-150) that the path opened up by the fluke in the sheep's body also allows the entry, establishment, and rapidly fatal spread of the gas gangrene gacillus, *B. oedematiens.* Thus the extermination of fluke carriers in the district becomes a matter of importance.

Amongst the fresh-water shells sent down were several specimens of a *Planorbis* which at once appeared distinct from *corinna,* no examples of which occurred. On being informed of the interest of his discovery, Mr. Hopkirk searched diligently for more specimens, and sent down a full range from adult to juvenile, though he stated that the draining of the swamps then in progress was making this species increasingly rare. We are perhaps fortunate to have received it before it was exterminated. It may be described as follows.

Planorbis kahuica n. sp. (Text-Figs. 1, 2, 3).

Shell very similar to *P. corinna,* but more rapidly expanding. No sculpture beyond fine oblique growth lines. Colour dark greenish-brown, whitish in places, hardly shining; some are light greenish-horn, and this is probably the true colour, the dark layer being a fresh-water deposit. Spire relatively more sunken than in *corinna.* Protoconch indistinct, but apparently larger and less regularly globular than in *corinna.* Whorls three (*corinna* has nearly four—or perhaps more), more convex than in that species, especially the inner ones, and increasing in width more rapidly; each whorl is twice the width of its predecessor at the same spot, but only one and a third times in *corinna;* this makes the two species reach about the same size in the end, in spite of the difference of a whorl. Suture deeper, sub-canaliculate, bordered by a distinct narrow flat space before the convexity of the whorl begins (this is absent in *corinna*). Base much less

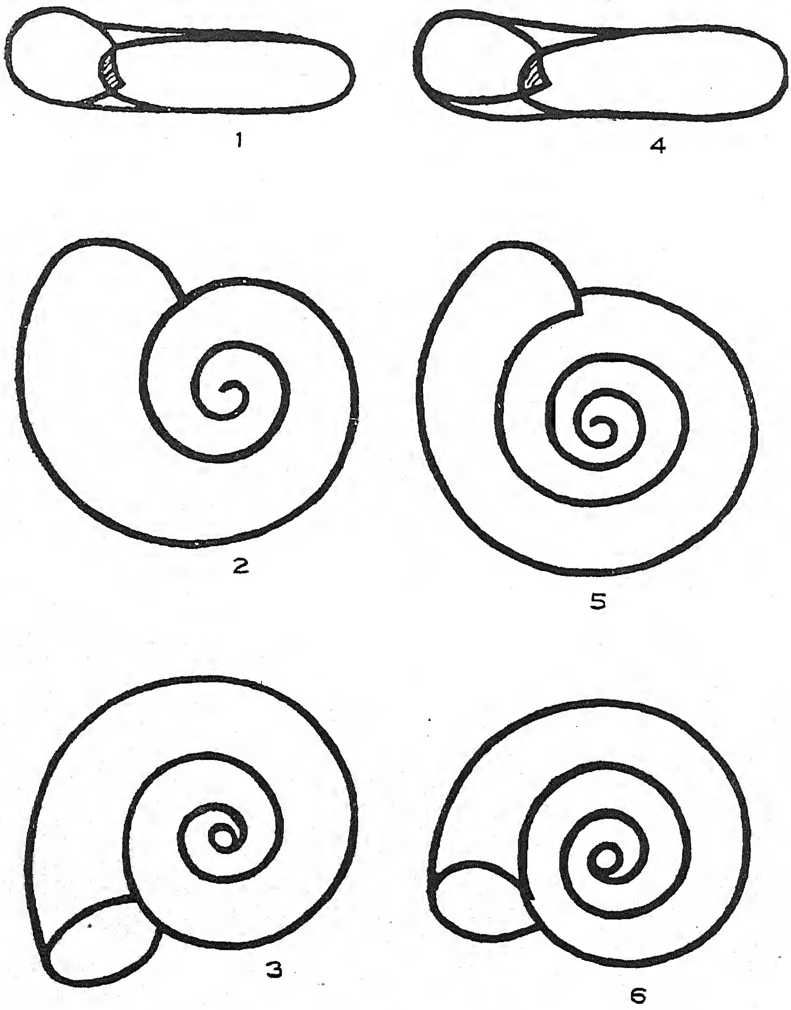
excavated, the difference in the width of the whorls being very noticeable from below. Aperture much as in *corinna,* but more rectangularly oval, with a slight tendency to an upper carina (not well shown in the figure).

Major diameter, 3.9 mm.; minor diameter, 3.5 mm.; height, 1 mm. (type, 3 whorls).

Corresponding dimensions for paratype, $2\frac{3}{4}$ whorls; 2.7 x 2.4 x 0.8 mm.

Corresponding dimensions for *corinna* (4 whorls); 3.3 x 2.6 x 0.8 mm.

Corresponding dimensions for *corinna* ($2\frac{3}{4}$ whorls); 1.6 x 1.4 x 0.3 mm.



FIGS. 1, 2, 3.—*Planorbis kahuica* n. sp.: holotype × 15.5.
FIGS. 4, 5, 6.—*Planorbis corinna* Gray: topotype × 19.

Locality—Raupu swamp and dam, Rissington, Hawke's Bay (type, and numerous specimens). Also Poututu, Gisborne, a few specimens collected by C. S. M. Hopkirk, also Lake Tutira, Hawke's Bay, a number of dead shells collected with *Potamopyrgus, Myxas, Isidora, Gundlachia,* and *Sphaerium* in shore-drift by Dr. R. S. Allan.

Type in Finlay collection.

Suter gives the dimensions of a specimen of *corinna* of four whorls as 4.5 x 1.1 mm.; if these figures are correct, his shell must have had more than four whorls. A topotype of *corinna* (4 whorls) is here figured (Text-Figs. 4, 5, 6) for comparison with *kahuica.*

Apparently this species is limited to the Hawke's Bay district, to the exclusion of *corinna.* Suter gives "Petane" amongst the localities for the latter, but he probably had unknowingly specimens of this new species. Perhaps the reason for this restriction is supplied by Mr. Hopkirk's remarks on the pH (hydrogen ion concentration) of the Hawke's Bay water (*l.c.*, p. 176). "The Hawke's Bay water is 7.2 or thereabouts, while water at Wallaceville is at least as acid as 6.4; again, just outside the range of fluke-infestation of sheep, the pH is 6.8." Neutral water has a pH of 7.0-7.1, so that the swamp water in which this *Planorbis* lives is very faintly alkaline. We suggest that *corinna* cannot live in neutral or alkaline water, while *kahuica* depends for its existence on the absence of acidity. Actual experiments to prove or disprove this would be interesting. It is well known that *Planorbis* in other parts of the world is very sensitive to local conditions, and this is probably the case here.

"Kahu" is a Maori personal name, and was part of the tribal name of the principal Maori tribe in the Hawke's Bay district.

Notes and Descriptions of New Zealand Lepidoptera.

By Alfred Philpott, Hon. Entomologist, Auckland Museum.

[*Issued separately, 23rd May, 1931.*]

Selidosemidae.

Selidosema melinata Feld., *Reis Nov.*, 129, 9.

S. scariphota Meyr., *Trans. N.Z. Inst.*, 47, 202.

I think the above emendation is necessary. There is a good series of *melinata* in the Clarke coll. and also an example of *scariphota*, verified by Mr. Hudson. I cannot see any definite distinctions between the two species.

Phycitidae.

Epicrocis sublignalis Walk.

An example of this Australian insect taken at Lake Rotomahana in February, 1915, is in the Clarke collection. For the determination of this and three or four other Australian species mentioned below, I am indebted to Dr. A. Jefferis Turner, who has also very kindly supplied notes on the distribution of the different forms. Dr. Turner states that *sublignalis* is extremely abundant in East Australia and is also found in Tasmania and Lord Howe Island. He suggests that it may have been imported into New Zealand in fodder.

♂. 25 mm. Head, thorax and abdomen fawn. Maxillary palpi with an apical bunch of long radiating hair-scales. Forewings with costa almost straight, apex obtuse, termen oblique; fawn sprinkled with white along costa and dorsum; a linear brown apical mark and some brown on dorsum. Hindwings pale ochreous, faintly purplish brown tinged round apex and termen.

Crambidae.

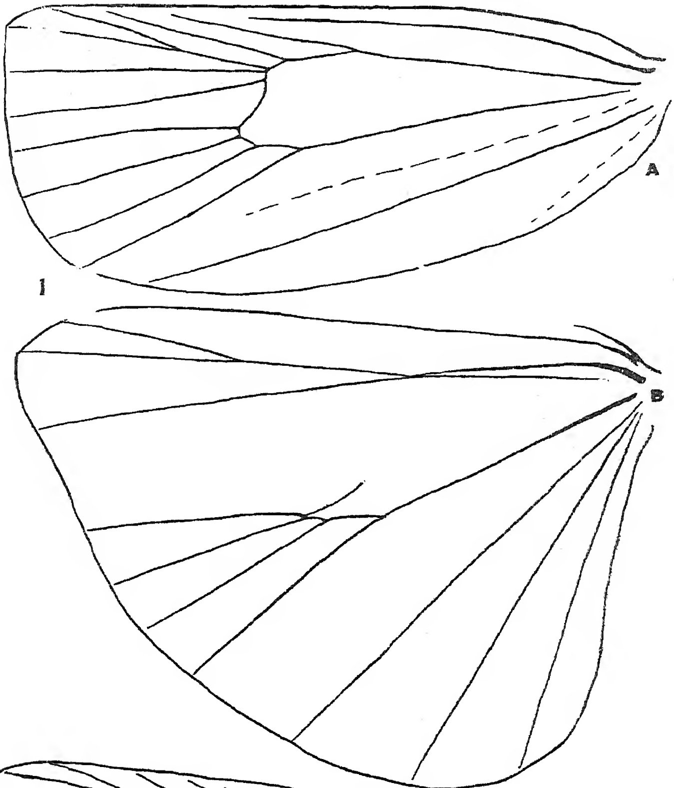
Crambus malacellus Dup.

A specimen of this widely distributed species was taken by Mr. C. E. Clarke at Whangarei in January. Dr. Turner says that it is found in Europe, India, Africa, Ceylon, Borneo and the East Coast of Australia as far as Sydney.

♂. 22 mm. Head white, palpi white, brown externally. Thorax white, tegulae purplish brown. Abdomen ochreous. Forewings narrow, costa slightly arched, apex acute, termen falcate; purplish brown; a broad snow-white stripe along upper half of wing, attenuated apically, and a similar but narrower stripe along dorsum. Hindwings white faintly tinged with brown round termen.

Tawhitia n. g.

Palpi, legs (except tibiae and tarsi) and thorax beneath densely haired, less so in ♀. Terminal segment of palpi concealed.



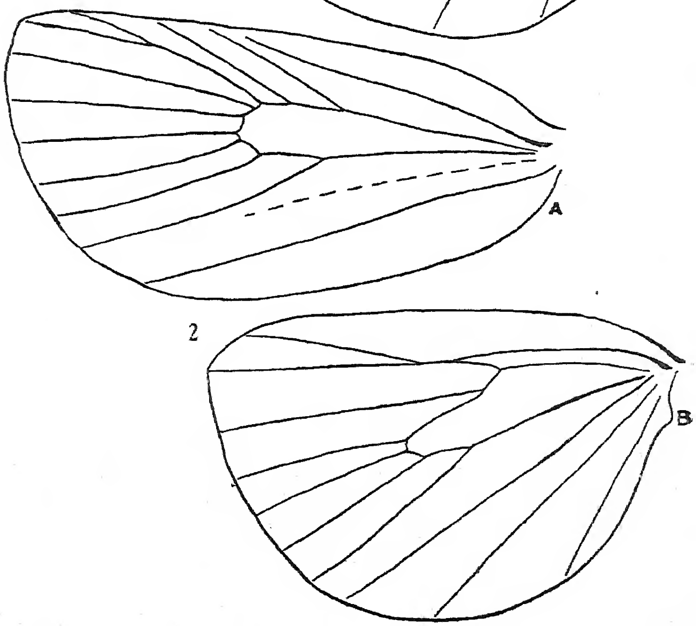


FIG. 1.—*Tawhitia glaucophanes* (Meyr.). A, forewing; B, hindwing.
FIG. 2.—*Tauroscopa gorgopis* Meyr. A, forewing; B, hindwing.

Antennae stout, filiform, pubescent. Maxillary palpi concealed in tuft of long hair. Forewings with 8 and 9 stalked, 7 and 8 closely approximated at origin. Hindwings with cell open (upper $\frac{2}{3}$, frequently more, of the transverse vein being absent), 4 and 5 connate or closely approximated, 6 out of 7, 7 and 8 anastomosing from (sometimes before) origin of 6 halfway to apex, basal portion of 7 lying close beneath 8.

Genotype: *Tauroscopa glaucophanes* Meyr. (Figs. 1 and 3).

Dr. A. J. Turner pointed out to me, several years ago, the difference in venational structure between *glaucophanes* and other species of *Tauroscopa*, and this, and the discovery that the male genitalia of the former were of a quite different type to the other species, convinced me that the erection of a new genus was advisable. The transverse vein is still represented in the genus by a vestige, which bends sharply backward from the origin of vein 5. This usually reaches to about the origin of vein 2, but is sometimes much shorter.

Tawhitia leonina n. sp. (Fig. 4).

♂ ♀. 24-29 mm. Head, palpi and thorax pale tawny. Antennae blackish. Abdomen dark fuscous, anal tuft tawny. Legs fuscous mixed with whitish ochreous, anterior tarsi suffusedly annulated with ochreous. Forewings suboblong, costa subsinuate, apex rounded, termen bowed, not oblique; light tawny; first line indicated by blackish posterior margining, slightly outwards curved, sharply indented below costa and broadly so beneath middle; second line faintly indicated, broadly excurved, serrated; an obscure but fairly large second discal spot usually present. fringes concolourous with wing. Hindwings greyish fuscous: fringes greyish fuscous with tips whitish and a dark basal line.

Differs from *T. glaucophanes* Meyr. in colour, a superficial character which is supported by differences in the male genitalia. Occasionally a specimen of *glaucophanes* may vary towards the colour-character of *leonina*, but in the latter there seems to be practically no variation.

Takitimu Mountains, in January. A good series of both sexes secured. Holotype (♂) allotype (♀) and a series of paratypes in collection Cawthron Institute.

PYRAUSTIDAE.

Scoparia subita (Philp.)

Orocrambus subitus Philp., *Trans. N.Z. Inst.*, 44, 116.

As intimated in a previous paper (*Trans. N.Z. Inst.*, 60, 497), the above systematic emendation is necessary.

Scoparia contexta n. sp.

♂ ♀. 29-32 mm. Head, palpi and thorax bluish grey. Antennae greyish fuscous, pubescent. Abdomen whitish grey. Legs fuscous, mixed with whitish, tarsi annulated with whitish. Forewings

elongate-triangular, costa subsinuate, apex rounded, termen bowed, oblique; bluish white; markings dull fuscous; 1st line irregular, hardly oblique; orbicular elongate-ovate, pale centred; claviform not indicated; reniform large, irregularly quadrangular, pale-marked interiorly; 2nd line deeply and angularly indented below costa; an obscure blotch opposite indentation of 2nd line; a line round termen, tending to break up into spots: fringes fuscous grey. Hindwings ochreous grey, tinged with fuscous round termen: fringes ochreous whitish.

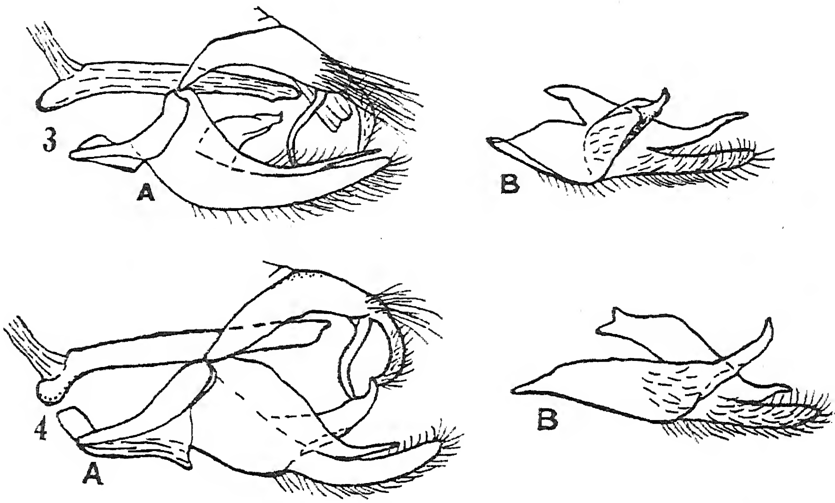


FIG. 3.—*Tawhitia glaucophanes* Meyr. A, male genitalia, lateral view; B, harpe, inner view.
FIG. 4.—*Tawhitia leonina* n. sp. A, male genitalia, lateral view; B, harpe, inner view.

Belongs to the *petrina* group, but is distinguished from its allies by the bluish white ground colour.

Mount Moltke, from 4,000 ft. to 5,000 ft., in January. Three males and a female captured by Mr. C. E. Clarke. Holotype (♂), which is the only example in good condition in coll. Auckland Museum.

Scoparia gyrotoma Meyr., *Trans. N.Z. Inst.*, 41, 7.

Scoparia repercussa Philp., *Trans. N.Z. Inst.*, 60, 301.

Mr. G. V. Hudson has pointed out to me that my *repercussa* is equal to *gyrotoma* Meyr. All examples of *gyrotoma* in New Zealand collections are in very poor condition, but on close re-examination I have no doubt that *repercussa* must sink as a synonym of *gyrotoma*.

PYRALIDAE.

Aglossa cuprealis Hb.

A specimen taken by Mr. Clarke at Papakura, Auckland, in January. Meyrick (*Revised Handbook of British Lepidoptera*,

p. 446) states that the species is found in England, Central and South Europe, Central Asia, North Africa, North and South America and Australia. The larva occurs in silken galleries amongst chaff, maize, etc.

♂. 22 mm. Head and thorax dark purplish brown. Abdomen ochreous mixed with brown. Forewings with costa straight, apex moderately acute, termen rounded, oblique; dark purplish brown mixed with ochreous; lines ochreous, serrate; 1st moderately broad, outwardly oblique; an indistinct interrupted median line; 2nd strongly and broadly excurved in disc. Hindwings pale ochreous white.

Gauna aegalis Walk.

Apparently not uncommon in the Auckland Province. The Clarke collection contains several taken at Papakura in December and January, and Mr. A. T. Pycroft has taken two or three near Auckland city in September and January. Dr. Turner gives the Australasian distribution as from Brisbane to Tasmania and states that the larvae feed on woody galls on various species of *Acacia.*

♂ ♀. 24-30 mm. Head, thorax and abdomen pinkish brown sprinkled with ochreous. Forewings elongate-triangular, costa sinuate, apex moderately acute, termen sinuate, oblique; pinkish brown; costa dotted from base to 2nd line with ochreous; 1st line ochreous, inwardly oblique, strongly margined on lower ⅔ with dark reddish brown; 2nd line ochreous, gently excurved on upper ¾ then sharply bent outwards to dorsum; terminal area dark reddish brown, paler towards tornus. Hindwings pinkish brown towards base and reddish brown towards termen; space between 1st and second lines whitish ochreous sprinkled with brown.

EUCOSMIDAE.

Eucosma mochlophorana Meyr.

Exoria mochlophorana Meyr., *Trans. N.Z. Inst.*, 15, 65.
Epiblema aphrias Meyr., *Trans. Ent. Soc. Lond.* (1901), 578.
Eucosma mochlophorana Meyr., *Trans. N.Z. Inst.*, 43, 88.
Eucosma aphrias Meyr., *Trans. N.Z. Inst.*, 47, 198.
Raumatia trimaculata Philp., *Trans. N.Z. Inst.*, 59, 488.

Eucosma potamias Meyr.

Eurythecta potamias Meyr., *Trans. N.Z. Inst.*, 41, 11.
Raumatia potamias Philp., *Trans. N.Z. Inst.*, 59, 488.

Eucosma fugitivana Meyr.

Protithona fugitivana Meyr., *Trans. N.Z. Inst.*, 15, 62.
Eucosma fugitivana Meyr., *Trans. N.Z. Inst.*, 43, 88.
Eurythecta varia Philp., *Trans. N.Z. Inst.*, 48, 421.
Raumatia varia Philp., *Trans. N.Z. Inst.*, 59, 488.

Correspondence with Mr. E. Meyrick has resulted in the elucidation of the synonymy of the above three species of Eucosmidae. Should it be held advisable to remove these species generically from *Eucosma, mochlorphorana* should be placed in *Exoria* and *potamias* and *fugitivana* in *Protithona.*

Acharneodes querula Meyr.

Eucosma querula Meyr., *Trans. N.Z. Inst.*, 44, 125.

I learn from Mr. E. Meyrick that in 1926 he formed the genus *Acharneodes* to include *querula* and a few other species, the type being *helota* Meyr., I subjoin the diagnosis of the genus.

"Palpi moderate, subascending; second joint expanded with dense scales towards apex; terminal joint minute. Thorax without crest. Forewings in ♂ with or without costal fold; 3-5 not approximated towards termen. Hindwings in ♂ with more or less developed subdorsal hair-pencil in groove or dorsal fold; 3 and 4 connate, 5 closely approximated at base, 6 and 7 closely approximated towards base."

ELACHISTIDAE.

Elachista stellata n. sp.

♂. 7.5 mm. Head, antennae, thorax and abdomen bronzy brown. Palpi bronzy brown mixed with whitish. Legs bronzy brown, tibial spines on posterior pair white. Forewings with costa subsinuate, apex rounded, termen very oblique; bronzy brown; a large snow-white spot on costa at $\frac{5}{6}$ reaching halfway across wing: fringes fuscous grey. Hindwings and fringes greyish fuscous.

The prominent white costal patch distinguishes this species from the other examples of the genus.

Pembroke, in December. A single male taken by Mr. C. E. Clarke. Holotype (♂) in coll. Auckland Museum.

SCYTHRIDAE.

Scythris nigra n. sp.

♂. 12 mm. Head, palpi, abdomen and thorax dark purplish fuscous. Antennae purplish fuscous, ciliations in ♂ $\frac{1}{2}$. Legs dark purplish fuscous, tarsi without annulations. Forewings with costa moderately arched, bent at $\frac{1}{3}$, apex acute, termen extremely oblique; dark purplish fuscous sparsely sprinkled with white scales: fringes dark fuscous. Hindwings and fringes dark fuscous.

Recognisable at once by the very dark colouration.

Mount Maungatua, in December. Two males taken by Mr. C. E. Clarke. Holotype (♂) in coll. Auckland Museum.

OECOPHORIDAE.

Leptocroca aquilonaris n. sp.

♂ ♀ . 16-20 mm. Head, palpi, antennae and thorax greyish fawn. Abdomen greyish fawn, segmental divisions paler. Legs greyish fawn, tarsi obscurely annulated with paler. Forewings with costa well arched, apex blunt-pointed, termen rounded, very oblique; pale greyish fawn more or less irrorated with dark brown; markings dark brown; a suffused blotch on costa at $\frac{1}{4}$, sometimes continued as an obscure fascia across wing and enclosing 1st discal and plical spots; plical rather larger than 1st discal and obliquely beyond it; 2nd discal obliquely transverse; an ill-defined blotch on costa at $\frac{3}{5}$; a strongly angled subterminal line: fringes greyish fawn mixed

with dark brown. Hindwings and fringes greyish fawn, veins outlined in dark brown.

Nearest to *L. vacua* Philp., but the male genitalic characters at once separate it.

Kauri Gully, Auckland, and Whangarei, in January. Three males and a female, secured by Mr. C. E. Clarke. Holotype (♂) allotype (♀) and paratypes in coll. Auckland Museum.

Leptocroca lenita n. sp.

♂. 18 mm. Head dull ochreous. Palpi ochreous, second segment fuscous externally except at apex. Antennae ochreous mixed with fuscous, ciliations in ♂ $\frac{3}{4}$. Thorax pale and dark brown mixed. Abdomen ochreous, middle of segments brassy. Legs ochreous, anterior pair fuscous. Forewings elongate, costa moderately arched, apex broadly rounded, termen rounded, oblique; ochreous white, densely irrorated with pale brown; markings obscurely formed by aggregations of brown scales; an irregular fascia from costa at base to dorsum at $\frac{1}{3}$, enclosing a blackish brown spot below fold; a broad fascia from costa at $\frac{1}{4}$ to before tornus, enclosing rather large blackish brown 1st discal spot; plical spot small, blackish brown, obliquely beyond 1st discal; a very obscure fascia, indicated by patch on costa at $\frac{3}{5}$, enclosing 2nd discal; an interrupted curved subterminal fascia: fringes whitish ochreous. Hindwings silvery grey: fringes ochreous.

Paler in colour than any other member of the genus except *L. lindsayi* Philp., from which species it differs greatly in the male genitalia characters.

The type specimen was found among some lepidoptera presented to the Auckland Museum by Mr. G. V. Hudson. From the donor I learn that it was captured in the Buller Gorge, near Newton's Flat, on 29th December, 1918. Holotype (♂) in coll. Auckland Museum.

Gymnobathra aurata n. sp.

♂ ♀. 10-12 mm. Head, palpi and thorax purplish brown mixed with grey. Antennae fuscous, pubescent. Abdomen grey. Legs fuscous, posterior pair whitish grey, tarsi very obscurely annulated with paler. Forewings with costa slightly arched, apex broadly rounded, termen oblique; fuscous grey; some dark fuscous suffusion beneath costa at base; a large blotch of yellow beneath fold at base; a dark fuscous fascia with some admixture of yellow above fold from costa at $\frac{1}{4}$, slightly curved and not quite reaching dorsum with its extremity resting on a fairly large dorsal patch of yellow; an outwardly oblique dark fuscous fascia mixed with yellow from costa at $\frac{1}{2}$ coalescing above tornus with a similar but inwardly oblique fascia from costa at $\frac{3}{4}$; a very obscure terminal fascia of the same colours: fringes fuscous grey sprinkled with dark fuscous and white. Hindwings and fringes fuscous grey.

Not near any other *Gymnobathra;* superficially the species recalls a *Borkhausenia* of the *xanthomicta* group.

Opoho, Dunedin, in November and December. One female and a series of males taken by Mr. C. E. Clarke. Holotype (♂) allotype (♀) and several paratypes in coll. Auckland Museum.

Trachypepla minuta n. sp.

♂. 9 mm. Head, palpi, thorax and abdomen dark purplish fuscous. Antennae purplish fuscous spotted with whitish ochreous, ciliations in ♂ 5. Legs purplish fuscous, tarsi obscurely annulated with pale brownish. Forewings with costa subsinuate, apex rounded, termen slightly rounded, oblique; dark fuscous sprinkled with whitish blue; scale-tufts and markings black, margined with bright ochreous; a curved transverse scale-tuft at $\frac{1}{3}$ not quite reaching costa or dorsum; a similar but shorter tuft at $\frac{2}{3}$; a subterminal line parallel to apex and termen, posteriorly margined with whitish blue; termen margined with black: fringes purplish fuscous. Hindwings bronzy fuscous: fringes dark fuscous with thick darker basal line.

The small size of this handsome little species distinguishes it from all its New Zealand congeners at present described.

A single male taken in the Domain, Auckland, in December. Holotype (♂) in coll. Auckland Museum.

Proteodes clarkei, Philp., *Trans. N.Z. Inst.*, 56, 396.

When I described this species only the male was available for examination, but I am now in a position to deal with the female also. In the Clarke collection there is a series of over 30 specimens of this brilliant species and among them is a single female. The sex is semi-apterous. The forewings, which are of about normal length, are broadly lanceolate and the hindwings sabre-shaped. The colouring is as in the male.

CARPOSINIDAE.

Carposina marginata n. sp.

♂. 11 mm. Head and thorax white. Palpi white, fuscous laterally and beneath. Antennae white, ciliations in ♂ 2. Abdomen ochreous white. Legs fuscous mixed with whitish, posterior pair white. Forewings with costa moderately arched, apex rather angular, termen rounded, oblique; white, rather greyish except along costa; extreme edge of costa yellow more dilated on apical $\frac{1}{2}$; markings black; a spot below fold at $\frac{1}{4}$; a spot well below costa at about $\frac{1}{4}$ and another immediately beneath it; a large spot just above fold not far beyond the latter; a spot below costa at $\frac{1}{2}$; beyond this a spot in disc and another beneath and obliquely before it; a chain of spots round termen and a number of single black scales scattered about apical half of wing: fringes grey. Hindwings and fringes shining white.

Nearest to *C. maculosa* Philp., but at once distinguished by the small size and the yellow margin of costa of forewing.

Okoroire, in December. The unique specimen was captured by Mr. C. E. Clarke. Holotype (♂) in coll. Auckland Museum.

HELIODINIDAE.

Stathmopoda albimaculata n. sp.

♀. 15 mm. Head, palpi and thorax grey mixed with fuscous. Antennae greyish fuscous. Abdomen grey mixed with fuscous and

ochreous. Legs fuscous, whorls of spines on posterior pair white. Forewings with costa almost straight, subsinuate, apex rounded, termen extremely oblique; dull greyish fuscous, a little darker on and below fold; an irregular white blotch below fold towards base; a similar blotch near apex: fringes greyish fuscous round apex dark fuscous. Hindwings and fringes greyish fuscous.

No other *Stathmopoda* has the two white blotches which are the distinguishing marks of *albimaculata*.

Woodside, Taieri, in December. The single female was taken by Mr. C. E. Clarke. Holotype (♀) in coll. Auckland Museum.

Hyponomeutidae.

Tanaoctena dubia n. sp.

♂. 18 mm. Head and palpi dull ochreous. Antennae strongly bipectinated and with dense pecten, brown. Thorax pale brown. Abdomen whitish ochreous. Legs ochreous, anterior pair fuscous, tarsi annulated with ochreous. Forewings elongate-oval, costa strongly arched, apex broadly rounded, termen rounded, oblique; dull brownish; an inwardly oblique thick blackish fuscous mark in disc at about $\frac{1}{4}$; a small round blackish fuscous discal dot at $\frac{2}{3}$: fringes dull brown. Hindwings and fringes fuscous grey.

Dr. A. J. Turner determines this peculiar form as being congeneric with the Australian *T. ooptila* Turn., though the venational characters do not wholly agree.

Auckland, in January. One specimen taken by Mr. C. E. Clarke and a second by the late D. D. Milligan. Holotype (♂) in coll. Auckland Museum.

Plutellidae.

Orthenches disparilis n. sp.

♂. 14 mm. Head and thorax greyish brown, tegulae purplish. Palpi grey mixed with brown. Antennae brown annulated with white. Abdomen ochreous grey. Legs purplish brown mixed with whitish. Forewings with costa moderately arched, apex blunt pointed, termen hardly rounded, oblique; purplish fuscous, upper half of wing white, clear basally and becoming progressively more tinged with purplish fuscous after $\frac{1}{2}$; extreme edge of costa purplish fuscous near base; a triangular projection of fuscous half into upper portion at $\frac{1}{3}$ and a similar but larger projection at $\frac{2}{3}$: fringes purplish fuscous. Hindwings subtrapezoidal; greyish white, purplish-tinged towards termen: fringes ochreous white.

Superficially resembling some forms of *O. chartularia*, but the male genitalic characters are of a quite different character.

Kauri Gully, Auckland, in January. A single male captured by Mr. C. E. Clarke. Holotype (♂) in coll. Auckland Museum.

Orthenches chartularia Meyr., *Trans. N.Z. Inst.*, 55, 205.

O. nivalis Philp., *Trans. N.Z. Inst.*, 58, 89.

I now consider *nivalis* to be a synonym of the variable *chartularia*.

Orthenches similis Philp., *Trans. N.Z. Inst.*, 55, 211.

Mr. Hudson (*B and M of N.Z.*, 329) treats this species as a synonym of *O. semifasciata* Philp., but the differences in the male genitalia are most marked. The best superficial difference is the character of the white tornal fascia, which in *similis* is prominent and not dilated apically, while in *semifasciata* it is represented, if at all, by a broadly triangular indentation from the whitish costal area. Mr. Hudson's figure (of *semifasciata*) appears to have been taken from a specimen of *similis*.

TINEIDAE.

Archyala culta n. sp.

♂. 15 mm. Head and palpi greyish brown. Antennae grey annulated with fuscous. Thorax brown. Abdomen greyish brown. Legs greyish ochreous, tarsi annulated with fuscous. Forewings elongate, costa sinuate before middle, apex round-pointed termen straight, oblique; light grey: numerous fine curved transverse dark fuscous strigulae from base to apex; a very dark obscure fuscous linear marking in disc: fringes grey mixed with fuscous; base pale and a sub-basal blackish fuscous line. Hindwings purplish fuscous, darker apically: fringes dark greyish fuscous with darker basal line.

Somewhat resembling *A. paraglypta* Meyr., but the peculiar outline of the costa of forewings is a good distinguishing character; there is also no tendency for the strigulae to coalesce in pairs.

Opoho, Dunedin, in December. A single male taken by Mr. C. E. Clarke. Holotype (♂) in coll. Auckland Museum.

Tinea conspecta n sp.

♂. 8 mm. Head and palpi ochreous grey mixed with fuscous. Antennae grey annulated with black. Thorax ochreous grey mixed with fuscous. Abdomen greyish fuscous. Legs ochreous, tarsi annulated with fuscous. Forewings with costa almost straight, apex pointed, termen oblique; metallic purplish, densely irrorated with fuscous, brassy ochreous and white; a double white outwards-curved fascia at $\frac{1}{3}$, more or less interrupted, but dilated and prominent below fold; a similar but more obscure fascia at $\frac{2}{3}$; numerous interrupted white strigulae on apical $\frac{2}{3}$ of wing; a white spot on costa just before apex and one beneath it on termen: fringes fuscous grey.

Not very close to any other *Tinea;* the superficial appearance is singularly like an *Eschatotypa.*

The Domain, Auckland. One taken in November and a second in January. Holotype (♂) and a male paratype in coll. Auckland Museum.

Tinea belonota Meyr., *Trans. N.Z. Inst.*, 20, 99.

Gymnobathra zephyrana Clarke, *Trans. N.Z. Inst.*, 56, 419.

The above synonymic correction is necessary. *Tinea belonota* appears to be an extremely rare species. After Mr. Meyrick's capture of the type specimen in 1887, the species does not seem to have been met with by collectors till 1921, when Mr. Clarke took a single

specimen at Whangarei. There are now, however, two other examples in the Clarke collection, the first captured at Waikaraka, Whangarei, and the second at Okauia, Waikato.

HEPIALIDAE.

Porina gourlayi n. sp.

♂ ♀. 34-48 mm. Head and thorax pale to bright ochreous. Antennae ochreous, closely serrate in male and minutely ciliate. Abdomen greyish ochreous. Legs ochreous. Forewings moderate, costa subsinuate, apex rounded, termen rounded, oblique; pale whitish ochreous to bright ochreous; many fuscous-ringed pale-centered dots, the most prominent being a subtriangular one in disc and one, or two, others beyond it; there is usually a dot on costa near base and another obliquely below and beyond it; an obscure fuscous subterminal shade followed and sometimes preceded, by a chain of dots; a thick blackish fuscous streak from dorsum at base, reaching halfway to tornus, its upper margin irregularly dentate, the interstices being filled with whitish; a series of dark-centered lunules round termen: fringes concolourous with wing. Hindwings ochreous fuscous or pale greyish ochreous: fringes ochreous.

Nearest to *P. oreas* Huds. and *P. descendens* Huds., but differing from both in the markedly dentate dorsal streak. The female is commonly paler than the male, but not in all instances.

Flora Camp (3,000 ft.) Mount Arthur, in January. A good series of both sexes taken by Mr. E. S. Gourlay. Holotype (♂), allotype (♀) and paratypes in coll. Cawthron Institute; several paratypes in collection Auckland Museum.

Geology of the Papakura-Hunua District, Franklin County, Auckland.

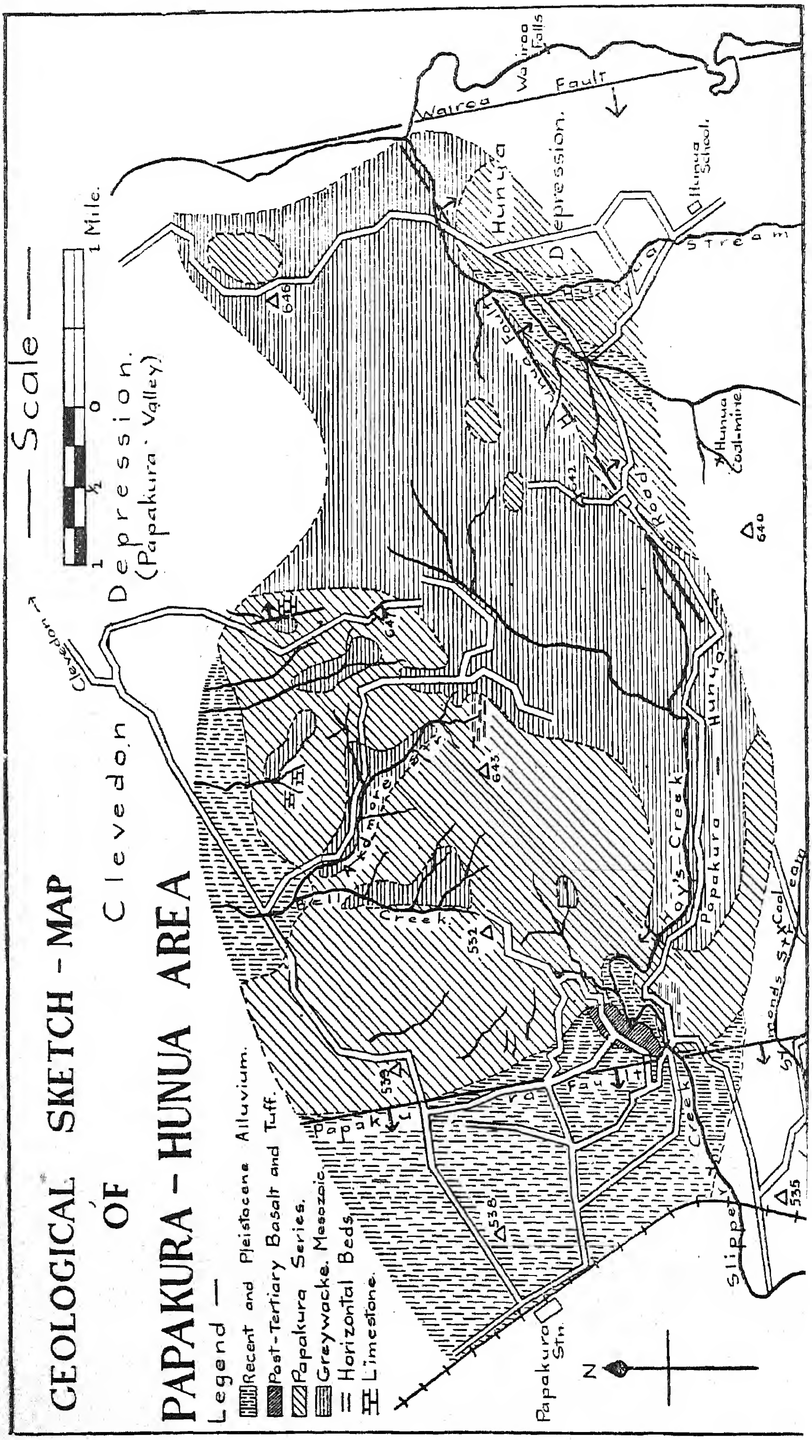
By C. R. LAWS, M.Sc., Dunedin Training College.

[*Read before the Otago Institute, 13th May, 1930; received by Editor, 3rd July, 1930; issued separately, 31st May, 1931.*]

CONTENTS.

INTRODUCTION AND PREVIOUS WORK.

THE investigation of the district described herein was undertaken in 1924 under the direction of Professor J. A. Bartrum of Auckland University College, who gave the writer a preliminary statement of his conception of the general structure of the district that has proved substantially correct. The results of the work were submitted as a thesis for the Master's degree, and read, in the form of a joint paper with Professor Bartrum, before the Auckland Institute in 1925. The


GEOLOGICAL SKETCH-MAP
OF
PAPAKURA-HUNUA AREA
Legend —
Recent and Pleistocene Alluvium.
Post-Tertiary Basalt and Tuff.
Papakura Series.
Greywacke. Mesozoic.
Horizontal Beds.
Limestone.
Scale
1 ½ 0 1 Mile.
Clevedon
Depression.
(Papakura Valley)
Clevedon
Wairoa Fault
Wairoa Falls
Hunua Depression.
Hunua School.
Hunua Coal-mine.
Road
Hunua
Hoy's Creek
Papakura
Creek
Papakura Stn.
Slippery Creek
Coal
Symonds St.
Stream
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writer wishes to express his thanks to Professor Bartrum for his readiness in giving assistance and criticism both in interpretation of the geology and in preparation of this paper. He is also indebted to Dr. J. Marwick for identification of fossil mollusca, and to Mr. A. H. Browne who supplied an analysis of coal occurring on his property.

Though many earlier workers have described parts of the area now studied, no full systematic description has previously been attempted. As far back as 1858, Hochstetter (1864) visited the district and separated the coal measures, which he placed in his Brown Coal Formation, from overlying beds which he called the Papakura Series, and correlated with the Waitemata Series of Auckland. He was followed by Hutton (1867), who correlated the limestone of the Papakura Series with a meridional strip of limestone south of Waikato Heads on the west coast of Auckland, placing it stratigraphically above the Brown Coal Formation and grouping both sets of beds as Eocene. In 1871 he agreed with Hochstetter in recognizing an unconformity between the brown coals and the Papakura limestone, but added a further one between the Papakura and Waitemata Series.

A brief report on the beds at Slippery Creek (Hay's Creek) is given by Park (1885), who collected fossils from the Papakura limestone there and noted that recent volcanic material covers the western slopes of Hunua Range. McKay (1888) observed that on its west side the coal beds dip north-east into the range, and recorded the presence in these strata of abundant impressions of fossil leaves, mostly of dicotyledons. He agreed with Hutton as regards the stratigraphic position of the Papakura Series, but claimed that there is no necessity for an unconformity between the limestone and the coal-bearing series, and predicted that work in adjacent areas would probably show that there is a conformable sequence from the coal to the upper surface of the Waitemata Series, and that the apparent unconformities would turn out to be due either to overlap or to dislocation.

More recently Clarke (1905) collected and described fossils from both the Waitemata Series near Auckland and the Papakura Series in the present area, while Bartrum (1922a) referred briefly to the origin of the silts laid down on the lowland around Papakura and northwards, which he regarded as being bounded along its eastern margin by ". . . . irregularly warped uplands of resistant rock due to faulting and flexure." Bartrum (1926) further has incorporated some of the results of the present study in his paper *"On the Western Coast of the Firth of Thames."*

Owing to lack of time during the preparation of his thesis in 1924, the writer was unable to map in detail several outliers of Tertiary rocks east of Trig. 647, and his subsequent transfer from Auckland unfortunately has prevented his completing the task.

GENERAL DESCRIPTION OF THE AREA.

The northern boundary of the district studied is provided by a narrow belt of lowlands constituting Papakura Valley or Clevedon

Depression, which extends east from Papakura to Clevedon. South of this the rugged uplands of Hunua Range rise gradually, and represent structurally a block tilted to the north-west. On the west of the area there is an abrupt rise to the elevated block of the Hunua uplands along a north-north-west–south-south-east scarp believed to be due to a fault here designated the Papakura-Drury Fault. The eastern boundary of the district is determined by natural features that form the eastern margin of Hunua Range, namely the lower course of Wairoa River and the intermontane lowlands here called Hunua Depression, whilst southwards, mapping ceased at an east-west line drawn through a point about a mile south of Papakura.

In the early days of colonisation the district was heavily forested, but the various lowland areas have long been cleared for cultivation, and, except for occasional small remnants, Hunua Range is also divested of its former cover of forest. Unfortunately, deforestation has been followed by abundant growth over large tracts of bracken fern and gorse, while in some places the blackberry has taken full possession, so that the location of outcrops in parts has been a matter of considerable difficulty. In addition, soil creep stimulated by deforestation has undoubtedly hidden outcrops that were available to earlier workers.

Synopsis of Structure and Topography.

The Papakura-Hunua area consists essentially of an uplifted block of Mesozoic rocks, partially covered by rocks of Tertiary age and constituting Hunua Range, which is bounded on the south-west by a strong north-east–south-west fault and on the east by converging fractures which have caused the downthrow of a wedge-shaped block represented by the Hunua depression, and is tilted to the north-west so that it passes below the Pleistocene and Recent filling of a fault-angle depression now occupied by the two-miles-wide Papakura-Clevedon Plain. This plain abuts northwards against the very clearly shown scarp of a strong fault of the north-east–south-west series recognised by Henderson (1924) as the dominant fracture series of the Taupo region.

West of Hunua Range there are lowlands, here called the Papakura lowlands, formed of pumice and other silts covered locally by basaltic débris, which Gilbert (1921) regarded as the filling of a former estuary of the Waikato River.

Nowhere in the area is there evidence of important folding post-dating the deposition of the Tertiary strata, though, as shown above, there is abundant proof of strong faulting. Cotton (1916) has described New Zealand as a "concourse of earthblocks," and the structure of the Papakura-Hunua district certainly accords with this view. This is strengthened by evidence from adjacent areas, for it is generally recognised that the topography of the country between Hunua Range and the east coast of the North Island near Coromandel Peninsula is largely governed by a series of powerful earth-fractures (See Bartrum, 1926). Henderson (1924) maps a series of parallel, alternately depressed and elevated blocks trending north-north-west from the Taupo-Rotorua region towards Hauraki Gulf, and it is the

continuation of this series of fractures that has given rise to the upland of Hunua Range with its lateral lowlands. Hunua Range forms a topographic element which has attained the physiographic stage of early maturity, for certain juvenile evidences persist in flat-topped areas suggestive of the original surface. The covering series of Tertiary sandstones is relatively poorly consolidated, so that consequent streams flowing westwards have cut through the cover to impose their courses on the resistant Hokonui greywacke of the basement. Superposed consequents are by no means general, however, for insequent streams have dissected the northern slopes of the range facing Clevedon.

A feature demanding comment is the bench-topography developed in the younger sediments, for frequently several benches form tiers towards the summits of divides, and are almost certainly to be ascribed to inequality in resistance to erosion of various members of the Tertiary sequence. (Fig. 1, Plate 1).

STRATIGRAPHY.

SUMMARY OF STRATIGRAPHY.

As already indicated, Hunua Range is a compound mass of sedimentary rocks. The oldest, which are greywackes of Mesozoic (? Trias-Jura) age, form essentially the core of the range, for they outcrop prominently in the higher and more central zone, though locally covered by caps of Tertiary strata, and have been located at low levels in several of the deeper valleys opening out on to the western lowlands. Along the slopes descending from Hunua Range northwards to the Papakura Valley depression they are exposed at very low altitudes as they pass below the younger deposits of this lowland, and on the east flank of the range they outcrop at the level of Hunua Depression. In addition, at the northern end of the range, an upland diverges eastwards to Wairoa River, and here, as elsewhere, greywacke forms the basement and outcrops along the southern slopes descending to the lowlands near Hunua as well as in the deep gorge by which Wairoa River escapes from the depression.

Earlier geologists referred these greywackes to the Palaeozoic, but later authorities place them in the Hokonui System of approximate Trias-Jura age.* Tertiary strata lie unconformably upon this Mesozoic basement and are extensively developed along the flanks of the Hunua uplands, whilst they form the greater portion of the divides in the neighbourhood of Hay's Creek and Ardmore Valley, and, further north, largely cover the slopes facing Clevedon and Ardmore Townships. They are again exposed in Hunua Depression, and on the high-level terraces between Papakura and Ardmore, which have been carved from the dip slope of the tilted block of the range.

In the lowland areas and in the valleys of Ardmore and Hay's Creeks, beds of the Tertiary sequence pass beneath Pleistocene fluviatile deposits, whilst volcanic lavas and tuffs of Pleistocene age cover them near the debouchure of Hay's Creek.

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*For example, Morgan, 1922.

The "hydraulic limestone" beds, called by Ferrar (1920) the Onerahi Series, and by him and many of the earlier workers of the Geological Survey relegated to the Upper Cretaceous*, is absent from the present area, though present not many miles north of Auckland City. Turner and Bartrum (1929) have discussed this fact and conclude that it is a consequence of unconformity between the Onerahi and Tertiary strata, though they have kept in mind (*op. cit.*, p. 884) the possibility that the area north of Auckland was depressed beneath the seas of late Cretaceous and Tertiary times earlier than that south of this city.

1. GREYWACKE OF THE HOKONUI SYSTEM (? TRIAS-JURA).

All exposures of the Mesozoic oldermass reveal a medium-textured greywacke which contains abundant partially-weathered grains of feldspar and fairly plentiful angular grains of quartz. There is no appearance of the argillite so prominently developed in the other similarly-constituted ranges forming the axis of the North and South Islands of New Zealand. Hochstetter (1864, p. 34) speaks of greywackes and "dioritic aphanite" as forming the "Palaeozoic" basement of the present area, but no rocks resembling the "dioritic aphanite" have been located.

In earlier Cretaceous times, at the close of the Hokonui period of sedimentation, strong compressive forces acting throughout the New Zealand area consolidated the sediments and raised them into high mountain folds with a north-north-east trend (Marshall, 1911, p. 38). Gregory (*fide* Marshall, *loc. cit.*, p. 38) claimed that there were two periods of folding in New Zealand, and that the older of them is found in the south-east trending axis of Otago and in North Auckland Peninsula, including thus the folded Trias-Jura rocks of the present district. In this connection Morgan (1922, p. 51) stated that throughout the North Island the strikes are variable, but that south of Auckland a north-north-east trend is most prevalent, whilst north of that city the average strike probably inclines decidedly to the west of north in sympathy with the trend of North Auckland Peninsula.

The original bedding of the greywackes is nowhere discernible, but the rocks are traversed by two systems of closely-spaced, rectangularly disposed joints, and so tend to break down on weathering into a fairly fine rubble of little use commercially even for road metal. They were searched for fossils, but none were found, as is the case in most other parts of New Zealand.

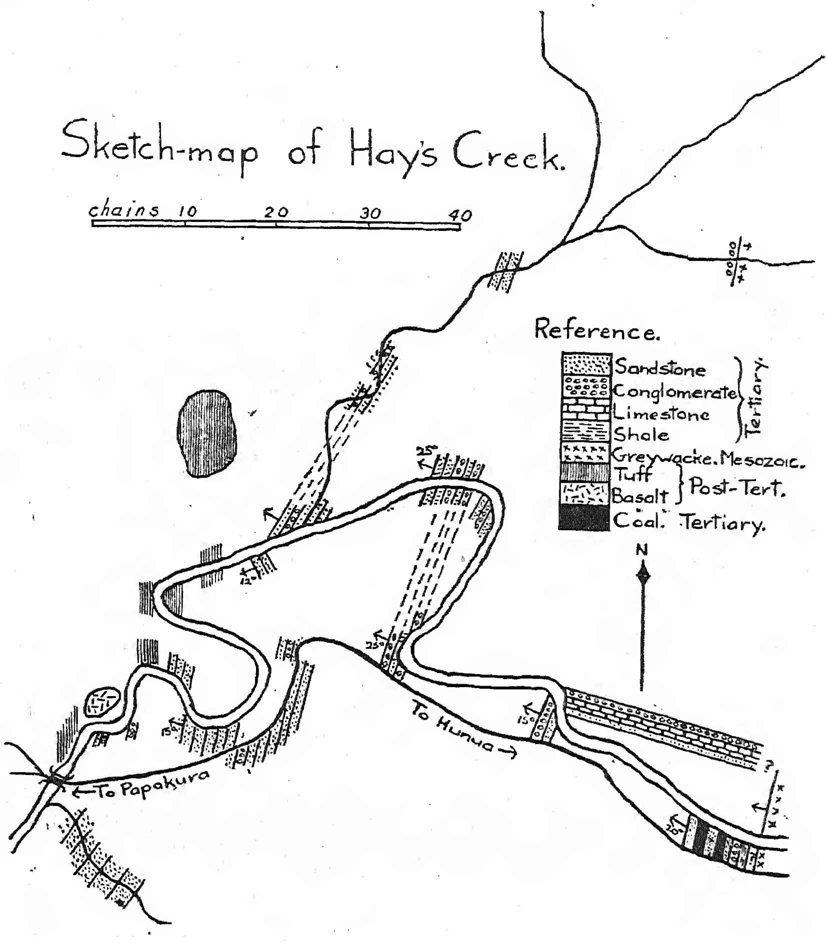
2. THE TERTIARY SEQUENCE (PAPAKURA SERIES).

Introduction.

The nature of the surface on which the Tertiary rocks rest unconformably will be considered in detail in a later section, and for the present it will suffice to state that it was essentially of low relief.

*In a recent paper Henderson (1929a) regards these beds as representing deposits of Danian and earliest Tertiary time.

In the several contacts discovered, the basal Tertiary beds are coarse conglomerates (Fig. 2, Plate 1), succeeded upwards by marine sandstones overlain by coals. The area of deposition of the coal-forming vegetation became more deeply submerged and marine sandstones were again deposited, and were followed by limestone, which was in turn covered by not less than 150 ft. of sandstones, usually with thin intercalated bands of conglomerate, or by beds of more argillaceous material. A minor angular unconformity occurs high in the succession (Fig. 3, Plate 1), and at several other horizons there is evidence of contemporaneous erosion, indicating, along with the intercalated conglomerates, that the area of deposition suffered numerous oscillations of level. In several instances the passage from sandstone to conglomerate and *vice versa* is gradual, but, in others, well-defined bedding planes, representing the diastems of Barrell (1917, p. 797), mark intervals between the times of deposition of successive beds.



Description of Occurrences.

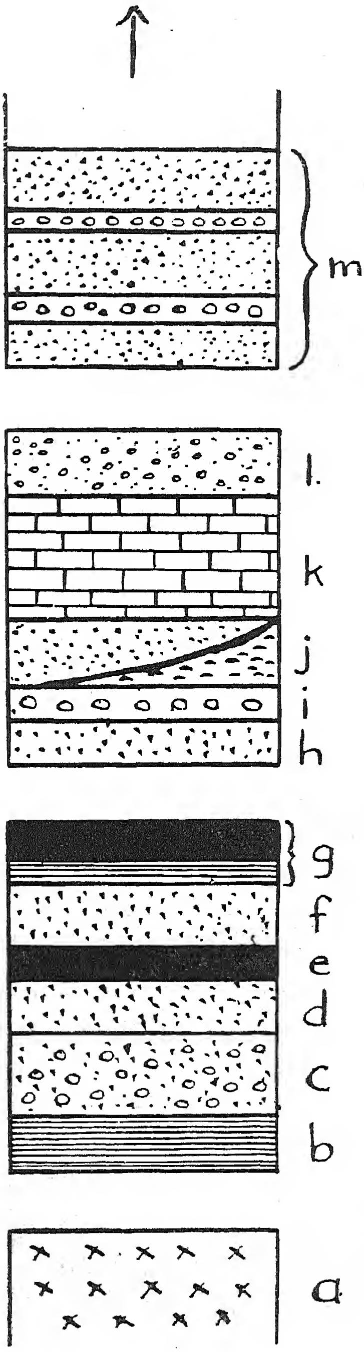
Hay's Creek Area.

In the valley of Hay's Creek there is a fairly complete section of not less than 200 ft. of beds that represent at least the lower portion of the Tertiary cover, beginning upstream from the bridge where the Papakura-Hunua Road crosses Hay's Creek and continuing for a distance of nearly half a mile to where the Hokonui greywacke appears, with its plain-like surface of contact dipping downstream below the younger strata. In this locality the Tertiary rocks have a general uniformity of strike and dip, the latter being constantly at a fairly low angle to the north-west, and suggesting that they have been subjected to a movement of tilting similar to that which has affected the major Hunua Range block.

At the top of the sequence sandstones occur at high levels along the flanks of the range both north and south of Hay's Creek, whilst similar rocks again appear at lower levels alongside Papakura-Hunua Road a little east of where it crosses Hay's Creek. Here they include somewhat decomposed fossiliferous greywacke conglomerate with abundant incoherent decalcified molluscan shells. (Fig. 4, Plate 2). With the included well-rounded pebbles of greywacke there are also several large boulders of this rock over 3 ft. in diameter, and, in addition, others of sandstone that seems indubitably Tertiary, along with occasional rounded pebbles of coal. The presence of the pebbles of Tertiary sandstone and coal bespeaks contemporaneous erosion in some adjacent locality, induced, as facts yet to be mentioned will show, by slight elevation of the sea floor, while that of the large boulders of greywacke indicates that the shore-line of the period was very close at hand.

A few chains north-east of this outcrop, near a sharp bend in the road, sandstones of a slightly lower horizon display the minor angular unconformity that already has been mentioned (Fig. 3, Plate 1), and, near at hand, there is a pocket of conglomerate, with a maximum depth of about 5 ft., in which there are, in addition to greywacke, fragments of mudstone derived from the Tertiary rocks. The conglomerate appears approximately at the horizon of the unconformity and gives further evidence that a slight uplift occurred, and allowed the erosion of earlier-deposited Tertiary beds.

Along the road sandstones outcrop for several hundreds of yards, but a section of more varied nature is yielded by exposures in the bed of the adjacent creek, and is illustrated by the accompanying stratigraphical column. At the mouth of the valley, and on the north side, basalt and associated tuff beds outcrop, with sandstone below the tuffs, and, for a distance of about half a mile eastwards, to a point a little upstream from the confluence of a tributary from the north-east, where a log-bridge spans the stream, similar beds with frequent intercalated conglomerate succeed one another with little variation. At the bridge there is a fine-textured conglomerate containing an abundance of brachiopod shells. Several hundred yards upstream from the brachiopod bed, near where the road closely approaches the stream, there is an outcrop of the limestone that is spoken of as the



TEXT-FIG. 1.
Stratigraphical Column to illustrate Succession at Hay's Creek. The breaks in the column indicate where outcrops were not found.

m. Upper portion of Tertiary Sequence. Sandstones and thin conglomerates often rapidly alternating.

Lower portion of Tertiary Sequence.

l. Fine pebbly conglomerate with occasional brachiopods.
k. Papakura limestone, 8 ft.
j. Grit pinching out to west and giving place to sandstone.
i. Coarse conglomerate with pebbles of coal, 2-3 ft.
h. Sandstone, lower limit not seen.
g. Upper coal bed and its underclay.
f. Unfossiliferous sandstone, 3-4 ft.
e. Lower coaly bed.
d. Unfossiliferous sandstone, 4 ft.
c. Conglomerate with cobbles of Tertiary sandstone, 12 ft.
b. Shale, lower limit not seen.

a. Hokonui greywacke (? Trias-Jura).

Papakura limestone dipping at 15° to the north-west, and overlying a soft greyish-white sandstone easily visible from the road (Fig. 5, Plate 2). The limestone is exposed in a bed 8 ft. thick for several hundred yards along the northern wall of the valley, forming part of a precipitous scarp some 20 ft. in height not far back from the stream. Above the limestone there is a thickness of at least 5 ft. of fine pebbly conglomerate containing a few brachiopod and oyster shells. Below it there is a grit bed 9 ft. thick with false-bedded lenses of limestone and sandstone rich in crinoidal remains, and, still lower in the sequence, further thin sandstone which rapidly wedges out eastwards and is replaced by a bed of grit with abundant nodules of iron pyrites. This is followed downwards by a band of conglomerate between 2 ft. and 3 ft. in thickness, and then by sandstone of undetermined but no great thickness.

There is clear evidence here again of the repetition of contemporaneous erosion of earlier-deposited beds of the Tertiary sequence, for this conglomerate contains rounded pebbles of impure lignite, whilst a little below it a rapidly-thinning black layer about an inch in thickness is composed of comminuted coal.

A few chains from these last outcrops, beds of the coal measures appear (Fig. 6, Plate 3), but their description will be reserved for the Appendix. Below them there is 3 ft. to 4 ft. of sandstone underlain by at least 12 ft. of a coarse conglomerate composed of cobbles of Tertiary sandstone; this overlies an exceedingly fine-grained, blue, greasy shale which is here the lowest bed of the sequence and is not 10 yards distant from the basement greywackes, though the actual contact is not visible.

In other sections showing the basal beds of the series, a conglomerate or breccia appears, and its absence in this instance calls for comment. The greywacke rises so steeply that the plane of separation is evidently inclined at a high angle to the horizontal, and, for several reasons, it is believed that the rocks here rest against the younger ones along a fault with a downthrow to the north-west. Examples of the occurrence of basal conglomerates, composed of greywacke débris, at the contact with the greywackes themselves are available in a small tributary of Hay's Creek, at a point about three-quarters of a mile to the north of this locality, and again further north in Ardmore Valley (Fig. 2, Plate 1).

The substitution, therefore, of Tertiary sandstone for greywacke in the Hay's Creek conglomerate shows that this latter probably is not near the base of the series, but that it was derived as the result of erosion of sandstones of the youngermass that had attained considerable thickness and consolidation in some closely-adjacent locality. We may therefore assume the presence, though now disguised by faulting, of a considerable thickness of beds intervening between this conglomerate and the basement rocks. Support of this assumption is afforded by a small stripped portion of the surface of the oldermass that may be observed further upstream for a distance of three or four hundred yards, which descends at an inclination of from 10° to 15° in a north-westerly direction. Its down-valley termination forms a somewhat dissected but nevertheless distinct scarp transverse to

the direction of the adjacent portion of Hay's Creek, and hangs a score of feet or so above the stream bed. This structural step is in fact marked by a small waterfall and by rapids, and it appears thus that the stripped greywacke surface is on the upthrow side of a fault, whilst the Tertiary beds under discussion have been downfaulted to the north-west.

Ardmore Valley Area.

In this locality the Hokonui rocks apparently form a decidedly irregular basement, for their surface rises from 250 ft. at the confluence of the three headwater streams of Ardmore Creek to 700 ft. on the divide immediately south-east of this, where they are capped by sub-horizontal sandstones of the Tertiary sequence. Below the crest of the divide there is evidence strongly suggestive of the probability that the sandstone is part of a series, overlapping upon an irregular basement, for it is in contact with abruptly rising Hokonui rocks. Reference to this fact will be made later in discussion of the nature of the surface of the oldermass.

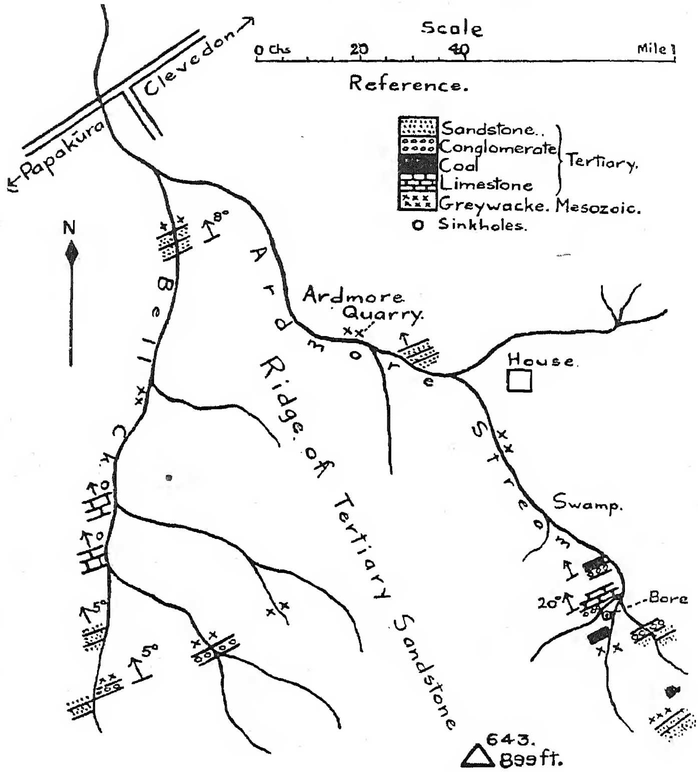
The lower beds of the Tertiary are exposed near the point of confluence of the three headwaters streams referred to above, and dip about 20° to the north-west. A disused shaft at this locality exposes carbonaceous shales with thin bands of lignite, and it is reported that the Mesozoic basement was encountered below these coaly beds at a depth of 45 ft. below the surface, whilst near at hand a greywacke conglomerate overlies them. Further, a chain north-west from the shaft similar conglomerate, here with fragments of oyster shells, forms the uppermost portion of a flaggy limestone at least 6 ft. thick, which is now rapidly being buried by modern swamp deposits. Measurements show that, in consequence of recent deforestation, the small swamp has been built up a height of at least 4 ft. in four and a-half years. Above the conglomerate there are sandstones with thin intercalated bands of mudstone and richly calcareous sandstone which are exposed almost continuously to a thickness of 650 ft. in passing upwards to Trig. Station 643, distant about half a mile to the south-west. Below the crest of the divide the strike is N.10°W. and the dip 5° to the west.

Bell Creek Area, Ardmore.

The valley in which Bell Creek flows heads south for a distance of about a mile from the junction of Ardmore Quarry Road and Papakura-Clevedon Road. Two points of contact between the older and younger formations were here located, the first in the bed of Bell Creek, about half a mile south of the junction mentioned, where a pocket-like lens of breccia-conglomerate rests on the irregular surface of the older rocks and is undoubtedly a shore-line deposit, possibly derived from an adjacent cliff in the ancient coast-line. A few inches above the basal conglomerate a discontinuous one-inch band, rich in foraminifera, lies just beneath a flaggy calcareous sandstone or arenaceous limestone (Fig. 7, Plate 3) with thin bands of mudstone, which strikes S.6°W. and dips at 8° to the north-west. This last bed is current-bedded and contains abundant plates and spines of echino-

derms and tests of foraminifera, as well as brachiopods and algae; it thickens downstream, where it includes water-worn pebbles of coal, due no doubt to the contemporaneous erosion of a seam elsewhere, for coal is found below the limestone at other localities in Hunua Range.

Sketch-map of Bell and Ardmore Creeks



About a mile south of the previous contact, the basal conglomerate is admirably exposed on the right bank of Bell Creek, resting on a worn surface of greywacke (Fig. 2, Plate 1). It contains broken shells of oysters and other molluscs and a few brachiopods, and is overlain by at least 20 ft. of sandstone, with poorly-preserved marine fossils, which dips at 5° to the north-west. These exposures are 230 ft. above sea-level, so that the surface of the Mesozoic rocks rises here in a southerly direction, a fact of importance, for it throws light on the structure of the Papakura Valley depression to the north and will be referred to subsequently.

On the west side of the valley, several hundred yards due north of this second contact, beds of fairly pure limestone, apparently about 30 ft. thick, are exposed in two sinkholes now almost completely masked by a tangle of vegetation. Most of the rock has a crystalline

appearance owing to the abundance in it of echinodermal material in addition to other organic fragments; in some parts of it small gritty particles of greywacke are common.

Area North-east of Ardmore Valley.

About half a mile north-east of Ardmore Quarry the valleys of two small streams flowing north-west down the dip slope of Hunua Range towards Papakura Valley contain outcrops of gently-dipping flaggy limestone about 7 ft. thick, which is marked by the somewhat lensoid bedding and lithological characters that distinguish the limestones of the area. The outcrops are limited ones lying below the level of adjacent greywacke, and show only that sandstone with a dip of 5° north-west by west comes in both above and below the limestone. Eastwards from here to Wairoa River, the surface of the Hokonui basement rock is more or less plain-like (Fig. 8, Plate 4), and slopes gently and regularly downwards towards Papakura Valley, capped here and there by sandstones of the Tertiary sequence.

About a mile east of the last-mentioned outcrops of limestone, there is a small valley draining to the north-north-west, in which a bed of sub-horizontal limestone 10 ft. thick, overlain by sandstone, abuts against greywacke exposed in a quarry a few feet from the Tertiary beds. The conditions of occurrence strongly suggest that the hidden contact is along a minor fault of the north-west–south-east series, the valley being excavated along the fault line, and it is indeed possible that the more westerly outcrop of limestone is depressed below the general level of the adjacent greywacke surface by similar faulting.

Stratigraphical Relations and Comparisons.

It has been shown that within the post-Hokonui strata of the Papakura-Hunua area there is no evidence suggestive of unconformity other than that exhibited alongside the road near the debouchure of Hay's Creek, where the upper beds are horizontally disposed upon the planed edges of gently-inclined lower ones, (Fig. 3, Plate 1), whilst shore-line conglomerates also mark the same horizon (Fig. 4, Plate 2). It will be remembered, however, that there is frequent evidence of contemporaneous erosion, especially in the Hay's Creek area, whilst the deposits throughout are distinctly of a near-shore or shallow water facies, so that it is obvious that the area of sedimentation underwent quite a number of rhythmic minor oscillations of level.

The Tertiary sequence in several other parts of the North Island, unlike that in the South Island, is broken by unconformities into several subdivisions, for Henderson and Ongley (1920, p. 31) mentioned at least two unconformities in the Gisborne and Whatatutu Subdivision, whilst in the Mokau district the same writers (1923, p. 16) reported that the Tertiary strata are broken into five series by periods of elevation and erosion. Even in the South Island the observations of Morgan (1916) and others, especially Speight and

Jobberns (1928), indicate that the New Zealand area suffered several transgressions and regressions of shallow seas during the Tertiary.

Reference to Hutton's report on the Lower Waikato (1867) shows that the vertical range of Tertiary strata is there substantially the same as in the present area, for, in each case, the Hokonui basement is overlain by coal beds, above which is limestone followed by sandstones. The same writer (1871, p. 248) made a statement of his views regarding the correlation of Tertiary beds in the Waikato and in the Drury-Papakura district. He regarded the coals of both districts as constituting the one horizon, but inclined to the opinion that the Papakura Series represents the base of a series increasing in thickness southwards which he called the Aotea Series.

In each district he postulated two unconformities in the Tertiary succession, for he believed that beds of the Papakura and Aotea Series rest unconformably on the coals, and that they are in turn covered unconformably by sandstones, those above the Papakura Series being the Waitemata beds of Auckland.

The present writer has found no evidence leading him to believe that the unconformity demanded by Hutton immediately above the coals is actually present, although, as already stated in description of the beds at Hay's Creek, he found pebbles of coal in a conglomerate above the coal, which there is undoubtedly conformable with overlying Tertiary beds. This certainly shows that erosion of the coal was proceeding in an adjoining area, brought about by some change of geographic conditions affecting local erosional processes, so that local unconformity may reasonably be expected, though it can by no means be assumed that widespread uplift and erosion occurred.

With regard to Hutton's other unconformity, Morgan (1916) stated that the unconformity placed by this writer between the Aotea (Papakura) Series and the Waitemata Series had been disproved by Clarke in his 1905 paper; Clarke's conclusion appears to be thoroughly justified.

The well-known "hydraulic limestone" (Onerahi Series of Ferrar), which is near the base of the post-Hokonui strata of North Auckland, and which is believed by many workers to rest unconformably below the Waitemata beds, is absent from the Papakura-Hunua district, for, as Bartrum (1924a) stated, in a report upon the Riverhead-Kaukapakapa district near Auckland, the Waitemata beds rest directly on the Trias-Jura in areas south of Auckland city. He explained this relation by an hypothesis of "... progressive subsidence of a Trias-Jura basement that is undergoing accompanying tilting or warping below the seas in which later sedimentation is proceeding." (Bartrum, 1924b).

Conclusions Regarding Correlations.

The writer considers that the relations of the members of the Tertiary series are to be explained by overlap on an unevenly-subsiding basement of Trias-Jura rocks, submergence occurring first towards the south. Expectably, then, beds of the Papakura Series

would appear close to the basement at the more northerly points nearer Auckland City, the underlying coals coming in further south, and this is actually seen in the occurrence at Maraetai, some 13 miles east of Auckland City, of the Papakura limestone resting hard on the Trias-Jura rocks as described by Park (1890). On approaching the areas of "hydraulic limestone" north of that city, higher Tertiary (Waitemata) beds rest on the Hokonui rocks, ultimately overlapping unconformably on to the Upper Cretaceous "hydraulic limestone" itself.

In the paper referred to above, Park stated that there is a direct sequence from the Fort Britomart beds of the Waitemata Series at Auckland to the Papakura limestone at Maraetai, and this section is of particular importance in that it is the only one directly connecting the fossiliferous "Orakei Bay beds" of Auckland with the limestone of the Papakura Series. The present investigations certainly support Park's belief (1890) that south of Maraetai conformably lower beds of the Tertiary sequence (Papakura Series) would be found resting conformably on the brown coal measures.

Park remarked that the absence of an equivalent of the Otatara limestone, which characterises the classic North Otago and South Canterbury areas, is a striking feature of the Tertiary sequence in the Waitemata and Papakura districts, but stated (1910, p. 116), however, that a calcareous sandstone or limestone in the Lower Waikato and adjacent localities contains fossils of Ototaran character. Marshall (1916) considered that all the Tertiary limestones of middle or lower Tertiary age throughout New Zealand (including the "hydraulic limestone") represent the one horizon, believing that they have been deposited at the time of maximum submergence during a widespread diastrophism, for they are all of moderately deep to deep water facies, so that it is not surprising, in view of the shallow water nature of the deposits of the Papakura area, that no comparable limestone horizon is represented there. He later (1924) urged strongly the Lower Tertiary age of the "hydraulic limestone." It is conceivable, however, that certain of the beds of the series may be the near-shore equivalents of deeper-water limestone laid down further off shore. Hutton (1871) remarked that the Papakura Series increases in thickness southwards towards the Waikato area, and, this being so, we may expect to find in that direction, which presumably was more remote from the ancient shore-line of the Tertiary seas, some record of the "missing" limestone. Such limestones do exist, but their relation to those of Papakura is not yet determined. The southward increase of thickness would accord well with the hypothesis advanced above that post-Hokonui sedimentation began and proceeded upon a differentially subsiding basement of Trias-Jura rocks progressively tilted towards the south. An alternative explanation, however, lies in accepting Thomson's (1917) suggestion of the existence of small diastrophic provinces, and assuming that subsidence throughout this entire province at no time attained the depth evidenced in others, especially in the South Island.

The presence of unconformities in the Tertiary naturally leads one to enquire whether they can be made use of in correlating the

beds in various districts. If the evidence were such that a general widespread diastrophism could be assumed, this method of attacking the problem would in all probability be highly profitable. But, as shown earlier in this paper, there is much that suggests that various parts of New Zealand have different diastrophic histories, so that one cannot place undue reliance on such a line of evidence, for, although various diastrophic regions may unfold parallel histories, they need not exhibit synchronism in the stages of their development. For the same reason correlations by means of lithology are hazardous, especially in districts, such as the present one, where rapid fluctuations of the shore-line appear to have occurred, and we cannot, therefore, unhesitatingly accept Marshall's (1916) view that there was only one main period of formation of limestone throughout early to mid-Tertiary times.

Finally, then, palaeontology must be considered, but, here again, difficulties arise, for as yet there are insufficient data to permit of any trustworthy correlations.

Hochstetter (1864, p. 43) concluded that the equivalence of the Waitemata beds and the limestone of Papakura cannot be doubted, for he found *Chlamys fischeri* (Zitt.) and casts of the pteropod *Vaginella* both at Orakei Bay, Auckland, and in the Papakura-Ardmore district. His opinion is supported by the work of Clarke (1905), who has been the only subsequent worker to collect and describe fossils from both the Waitemata and Papakura Series.

It may be of interest to mention that Powell and Bartrum (see Turner and Bartrum, 1929, p. 870) have investigated a bed with molluscan fossils which has recently been discovered at Waiheke Island, near Auckland, near the base of the Waitemata Series, and have correlated it with either the Hutchinsonian or Awamoan of Oamaru.

Palaeontology of Tertiary Strata.

Though fossils were collected by the writer from various horizons in the Tertiary sequence, their state of preservation is so unsatisfactory that Dr. Marwick, who kindly examined the molluscan remains, was unable to make much of them; none of the species that probably are new are sufficiently well-preserved for accurate description. Dr. Marwick stated in a letter that, in the absence of characteristic stage-marking fossils, the age of the Papakura-Ardmore beds cannot at present be fixed more closely than Upper Oamaruian.

The following are Dr. Marwick's determinations, as made by him in 1924:—

LAMELLIBRANCHIA.

Venericardia (*Pleuromeris*). n. sp.
Venericardia sp.; may be large specimen of the above.
Protocardia (*Nemocardium*) n. sp., cf. *pulchella* (Gray).
Limopsis sp. cf. *zitteli* Ihering.
Lutraria n. sp.
Pteromyrtea sp.

GASTEROPODA.

Sigapatella sp.

Polinices n. sp. cf. *kawhiaensis* (Marwick) and *unisulcatus* (Marwick).

Polinices cf. *scalptus* (Marwick).

The polyzoa were sent to Dr. G. H. Uttley, who has not so far found time to proceed with investigation of them.

Mr. F. Chapman of Melbourne University very kindly identified the following foraminifera (See Chapman, 1926, p. 20):—

Truncatulina haidingeri d'Orb.

Amphistegina lessoni d'Orb.

Clarke (1905) listed the following fossils recorded by Hochstetter (1864), himself and others from the Papakura Series. His lists have not yet received the revision necessitated by the intensive studies that have been made of the brachiopods and molluscs during recent years, but they are inserted here for convenience of reference, with the molluscan and brachiopod nomenclature brought up to date.

COELENTERA.

Flabellum laticostatum Ten.-Woods.
Flabellum papakurense Clarke.
Echinoderma.
Schizaster rotundatus Zitt.
Brachiopoda.
Tegulorhynchia nigricans (Sow.)
Terebratella novae-zelandiae Iher.
Terebratella sanguinea Leach.
Liothyrella gravida (Suess).

MOLLUSCA.

Pelechypoda.
Limopsis zealandica Hutton.
Glycymeris huttoni Marwick.
Crassostrea nelsoniana (Zitt.)
Gigantostrea wuellerstorfi (Zitt.)
Anodonta elliptica Hutt.
Pallium (*Felipes*) *burnetti* (Zitt.)
Chlamys fischeri (Zitt.)
Pallium (*Felipes*) *polymorphoides* (Zitt.)
Lentipecten hochstetteri (Zitt.)
Parvamussium zitteli (Hutt.)
Parvamussium papakurense (Clarke).
Limatula maoria Finlay.
Venericardia awamoaensis Harris.
Scaphopoda.
Dentalium solidum Hutt.

*Several years ago specimens of *Glycymeris* from Hay's Creek, Papakura, were sent to Dr. Marwick, who remarked in a private communication that these specimens do not agree exactly with any species so far described, and would appear to be nearest to a new species from Manaia Beach, Taranaki, which has a wide distribution in the Lower Wanganuian (*G. manaiaensis* Marw.).

Gasteropoda &c.
Sigapatella sp.
Polinices ovuloides (Marwick).
Maoricolpus caversamensis (Harris).
Vaginella aucklandica Clarke.

Plants.

Several impressions of dicotyledonous leaves were collected by the author, but, up to the time of writing, it has been found impossible to attempt identification of them. Von Ettingshausen's work (1891) on New Zealand Cretaceous and Tertiary flora, though not accepted by New Zealand geologists, has not yet been revised, and the same applies to the short list of species collected by Hochstetter in 1859 from the Papakura district.

3. Post-Tertiary Deposits.

The post-Tertiary deposits include those both of sedimentary and igneous origin, the former being confined mainly to the structurally depressed areas, although recent alluvium is also found in the valleys of Hay's Creek and Ardmore Stream.

On the lowlands around Papakura and northwards towards Otahuhu, railroad and road cuttings expose incoherent pumiceous silts, placed by Hochstetter (1867, p. 272) in his Lignite Formation of the Manukau Flats. They are believed by Gilbert (1921, p. 101) to have been brought down by the Waikato River from the pumice lands of the centre of the North Island, and deposited in a former estuary of that river, whilst the lignites accumulated in associated swamps.

In the lowlands of Hunua Depression recent silts of fluviatile origin rest on the eroded surface of Tertiary sandstones, forming extensive terraces many feet above the present level of adjacent streams.

Rocks of igneous origin are locally developed along the western edge of the Hunua Range and came from a vent near the debouchure of Hay's Creek, where both lava (Fig. 9, Plate 4) and tuffs (Fig. 10, Plate 5; Fig. 11, Plate 5) outcrop prominently, the tuffs in particular forming a lofty remnant of the earlier cone (Fig. 10, Plate 5). There appear to have been at least two major episodes of explosive activity, separated by one characterised by outpouring of lava. Basaltic lavas of similar type, with associated fragmental beds, also occur in the north-eastern portion of Hunua Depression, just outside the area selected for study.

Hochstetter (1864, p. 54; 1867, p. 268) evidently included these volcanic rocks with the volcanic "conglomerate" and flows of Drury and the Lower Waikato in his "Basaltic Boulder Formation," which he distinguished as distinctly older than the basalts of Auckland, for there the flows occupy the present valleys and are almost completely undecomposed, whereas those of the Waikato are considerably weathered and streams have cut deep trenches in them. He recorded the fact that the basalts overlie the Lignite Formation with its associated pumiceous silts, so that obviously the rhyolitic eruptions of the Taupo region preceded the basaltic ones of the Lower Waikato Basin.

GEOLOGICAL HISTORY OF PAPAKURA–HUNUA AREA.

Beds of the Hokonui System form the oldest surface rocks yet discovered in the North Island, though there is evidence of a pressure-affected earlier terrain, for Bartrum (1921a, pp. 120-21) recorded the presence of granulites in conglomerates intercalated in the basement Mesozoic shales and greywackes of Great Barrier Island, whilst he found similar evidence in another conglomerate near Whangarei (1921b, p. 128). Later the same writer (1924a) stated his conclusions that the granulated and sheared plutonic rocks of various conglomerates represent a now-buried terrain existing before and during the deposition of Trias-Jura sediments, and that this terrain apparently persisted into Tertiary times, for mid-Tertiary conglomerates with similar material appear not to be a re-wash of mid-Mesozoic ones.

In the present area, however, the conglomerates of Tertiary age that have been described entirely lack material of the kind recorded by Bartrum.

Benson (1923, pp. 37, 41) mapped the coastline of the land-mass that supplied the Trias-Jura sediments as trending approximately north and south adjacent to the west coast of New Zealand, and stated (*op. cit.*, p. 39) that this continent, which extended westwards over the present Tasman Sea and united New Zealand with Australia, remained above sea level until near the close of Jurassic times. At the close of the Trias-Neocomian period of sedimentation, however, the New Zealand area was elevated to form dry land, and the sediments were folded into mountain ranges, of which the " oldermass " of this paper forms the worn-down relics, for, as Cotton (1916) showed, long-continued erosion followed this orogeny.

Over the region now represented by North Auckland the truncated folds of this land-mass were next submerged beneath the Upper Cretaceous seas, where they were covered unconformably by ammonite-beds and the limestones, claystones and other beds of the Onerahi Series. In their turn, these Upper Cretaceous strata appear to have been uplifted and exposed to erosion and to have been removed from extensive areas. As a result of this emergence, and the longer one that preceded it, the land-mass had attained a very advanced stage in the cycle of erosion when depressional movements supervened, and it descended beneath the Tertiary seas to receive a cover of younger sediments. At first, basal conglomerates and associated marine beds were laid down, and then, during a temporary pause in the movement of depression, extensive swamps or lagoons came into existence near the coast. Over the present Lower Waikato area the coal-forming vegetation flourished more abundantly and the swamps assumed greater proportions than elsewhere, so that the seams of brown coal of that district attain considerable thickness and have considerable commercial importance. Near Papakura and Hunua, however, they are comparatively poorly developed and gradually thin out to the north, until near Auckland they have disappeared entirely. Subsequent progressive subsidence obliterated these low-lying swamps, and the coals became covered by the marine strata that now constitute the Papakura and Waitemata Series.

It is demonstrated by the characters of the sediments of the youngermass, and by the constant evidence of contemporaneous erosion they display, that the area was at no time deeply submerged and that the general movement of subsidence was of an oscillatory nature. Finally elevation ensued, and the compound mass became subject to normal subaerial denudation. Block-faulting, totally unaccompanied by folding so far as can be determined, then affected the area, and this was evidently a phase of the Kaikoura orogeny (Cotton, 1916, p. 248) which began probably in Pliocene times.

The subsequent history of the district is traceable only by reference to events near Auckland, which have been discussed by Bartrum (1922; 1929) and Turner and Bartrum (1929). Those of major importance include the filling of the downthrown block west of Hunua Range by the pumiceous silts brought by the Waikato River, and the subsequent sharp uplift by which deep trenches were excavated. These latter were later drowned by a submergence, sub-equal in amount to the uplift, which seems to have been the last diastrophic event of any real importance. Cotton (1916, p. 318) stated that these concluding movements, which he termed the post-Kaikoura movements, were epeirogenic rather than orogenic in character, and that there was evidence of a long period of rest between them and the earlier Kaikoura orogeny, during which the current cycle of erosion reached an advanced stage of development.

The upland block of Hunua Range has been sub-maturely dissected, but rejuvenation is shown in the fact that locally the streams have recently entrenched themselves to the extent of 6 ft. to 8 ft. below earlier flood-plains. Sub-Recent uplift has affected the whole Auckland area, for there are raised platforms and beaches, sometimes as much as 9 ft. above sea-level, around the shores of Hauraki Gulf, but it is doubtful if the rejuvenation can be a result of this movement, for it can scarcely have been reflected to so considerable an extent at parts of the stream courses that are relatively distant from the sea.

THE SURFACE OF THE OLDERMASS.

The pre-Tertiary surface carved upon the oldermass of the area examined appears in general to possess very slight relief (Fig. 8, Plate 4), and thus conforms with Cotton's (1916, p. 246) view of the nature of this surface throughout New Zealand. It is shown by adjacent regions that this condition is not merely a local phase, for the ranges north of the depression of Papakura Valley and the lofty uplands east of Hunua Depression are all marked by a striking accordance of summit levels and occasional plateau-remnants, and, although these areas were not examined, one strongly suspects that they are both structurally and stratigraphically akin to Hunua Range, though their elevation is such that all Tertiary beds have probably been stripped from their surface, whilst in Hunua Range this is not so.

There is, however, local conspicuous irregularity of the surface of the oldermass at the headwaters of Ardmore Stream, where, as already has been stated, the Trias-Jura greywacke rises into pro-

nounced crag-like inliers, abutting against the Tertiary beds. This naturally suggests the possibility that the abrupt contact is the result of faulting, especially as displacements of this nature are found elsewhere in the district, but no direct evidence has been found in support of this suggestion, although it could very readily explain the sharp difference in level of the basal Tertiary beds not far distant in the same valley, near the disused shaft referred to earlier in the paper, whilst similar steep contacts have been noted on the northern slopes of Hunua Range near Ardmore Village. The writer is therefore forced to consider the possibility that this crag represents a monadnock which was unreduced by the vigorous normal erosion that broadly levelled most of the surrounding surface. As depression continued, and as the Tertiary seas crept further landwards, the residual could then have persisted as a much-reduced island-remnant or stack, until it finally was completely submerged and buried by sandstones that now almost surround it, rising to a considerable height above it. There is, in fact, strong indication, along the course of a headwaters branch of Ardmore Stream flowing to the north-west, that such overlapping of the Tertiary beds upon the mid-Mesozoic basement as is here suggested actually has occurred, whilst the presence of large boulders of greywacke several feet in diameter in the basal conglomerates of the younger series exposed in the valley of a small tributary of Hay's Creek, as well as at higher horizons (as near the debouchure of Hay's Creek), shows that the advancing Tertiary seas locally developed greywacke cliffs of no mean height.

DETAILED STRUCTURE.

Fault Systems.

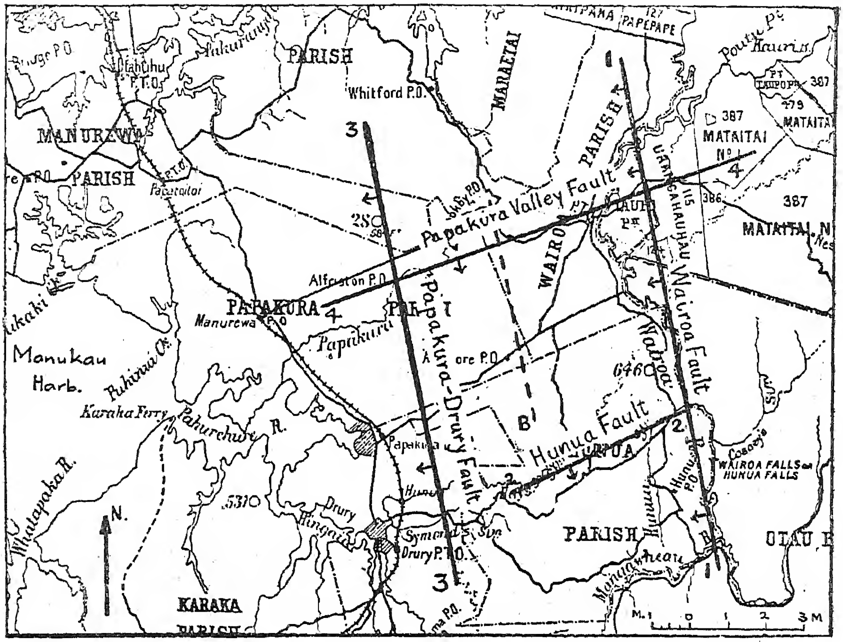
Inspection of the accompanying index-map will show that the present topography is largely governed by earth-fractures of two systems, which have variously uplifted and tilted adjacent earth-blocks. In all cases the scarps along the fault-lines are submaturely dissected; in some instances they are certainly true fault-scarps, but in others either fault-line scarps or composite fault-scarps, as defined by Cotton (1922, p. 172), for they seem largely, if not wholly, to be the result of selective erosion along fault-lines.

Wairoa Fault.

The most prominent fault of the district is that determining the eastern side of Hunua Depression, where its scarp delimits the high country to the east (the northerly continuation of Pakaroa Range). This fault trends north-north-west and south-south-east, and along its line Wairoa River has cut a deep subsequent gorge about three miles in length by which it escapes from the lowlands near Hunua. An upland that rises on the western side of the river at the northernmost angle of Hunua Depression, and constitutes an easterly extension of the northern portion of Hunua Range, with which it accords generally in altitude, has its general summit level fully 400 ft. below that of the high-level uplands on the other side of Wairoa River. This indicates that there has been a downthrow to the west of about 400 ft.

The continuation of this fault can be followed north-north-west beyond Papakura Valley lowlands by a prominent scarp, and accom-

panying discordance of level of approximately 400 ft. between surfaces of the relatively upthrown and downthrown blocks. As its line is followed south-south-east, however, from the outlet gorge of Wairoa River, the displacement is probably rather along a monoclinal flexure than along a fracture, for there seems here little trace of any true scarp in the long ridges running up from the lowlands to the high-level country eastwards towards the Firth of Thames.



INDEX MAP OF FAULTS.—1, Wairoa Fault; 2, Hunua Fault; 3, Papakura-Drury Fault; 4, Papakura Valley Fault. AB: Line of section across Clevedon lowland to show fault angle depression.

The Wairoa fault is possibly a continuation of a fracture mapped by Henderson (1924, p. 272) further south in the Waikato district. Whether this be so or not, major faults of similar trend characterise the adjacent regions, as instanced by the fractures that are responsible for the graben occupied by Hauraki Plains and Firth of Thames (See Henderson and Bartrum, 1913, p. 59; Bartrum, 1926), and by the Papakura-Drury Fault shortly to be described, which is the western limit of Hunua Range.

The suggested southern passage of Wairoa Fault into a monoclinal fold also finds parallel in the belief of Professor Bartrum* that the scarp on the east side of Hauraki graben, which is clearly due to fracture over the greater part of its length, gives place to monoclinal flexure where the railway to Rotorua ascends eastwards from the floor of the graben to the elevated plateau north of Rotorua.

*Private communication.

Hunua Fault.

The intermontane basin that has been called by the writer Hunua Depression represents a down-thrown block, more or less triangular in plan, with its apex directed towards the north. The down-throw has been brought about by the concerted action of Wairoa Fault and another, here called Hunua Fault, transverse to it, with a trend approximately east-north-east and west-south-west, which has its maximum displacement towards the north-east and appears to die out to the south-west. At the base of the scarp marking the line of this fault the lower portion of Hunua Stream flows north-east to join Wairoa River near the upstream end of its outlet gorge, its bed here being carved in Mesozoic rocks, though further to the south-west Tertiary sandstones rest at low levels against steeply-rising greywacke. Not far upstream from the confluence of this stream with Wairoa River, an isolated conical hill rises from the adjacent lowland almost at the foot of the scarp, and arouses interesting speculations as to its origin. One possibility is that it may represent a step, down-thrown by step-faulting; but its relative isolation and shape and the topographic characters of the adjoining scarp suggest that it more probably is a kernbut, or displaced rock-mass associated with rift-faulting, so named by Lawson (1903, p. 331; see also 1927, p. 248).

Papakura-Drury Fault.

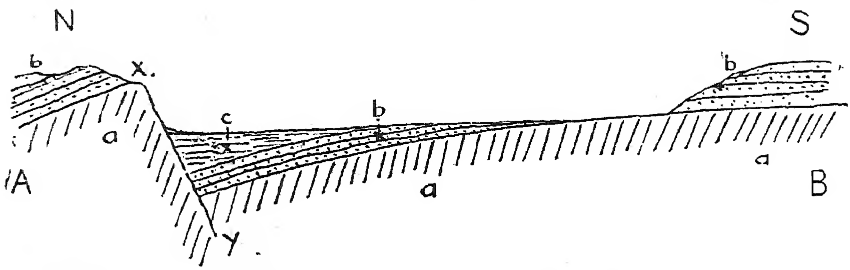
The Papakura-Drury Fault is a prominent fracture of the north-north-west series at the western margin of Hunua Range; the low-land on which Papakura and Drury are situated is believed to be a block down-thrown by it to the west, whilst the steeply-rising slopes of the range represent a scarp, probably a composite fault-scarp (Cotton, 1922, p. 172), due to the fracture.

From his examination of the coal beds exposed on the lower slopes of the upthrown Hunua block east of Drury, Cox (1882, p. 34) realised that the dip of the strata would not carry the coal below the flats to the west, but suggested that a fault may well do so, and recommended boring as the only means of ascertaining the facts. Long previous to this, at the instigation of Hochstetter (1864), the Auckland Provincial Government had put down two bores, but neither was sufficiently deep to reach the expected "Brown Coal Formation," and even in the deeper of two, which penetrated 65 ft., they encountered only surface clays and basaltic conglomerate and lava. Professor Bartrum has, however, drawn the writer's attention to the fact that several years ago the *New Zealand Herald* reported that the coal had been reached below the basalt in a bore near Drury Railway Station, so that there is now direct evidence of the relative down-throw, either by faulting or flexure, of similar horizons on either side of what is here believed to be a fault-line, though the extent of such down-throw is not ascertained.

Papakura Valley Fault.

The northern edge of the alluvium-floored Papakura Depression rests against a steeply inclined, fairly rectilinear scarp trending east-north-east and west-south-west, which is ascribed for several reasons

to the presence of a fault. The topographic evidence in favour of such interpretation is very strong, but even more cogent is the fact that the attitude of the Tertiary beds on the south side of the depression is continued in the hills about three miles north-east of Manurewa, where, as in the Ardmore area, the Tertiary beds rest upon a dip slope of greywacke inclined to the north-west. It is thus clear that, prior to the inception of the block-faulting that is postulated, the uplands both north and south of the Papakura-Clevedon lowland were united structurally as one great unit, the disruption of which by east-north-east–west-south-west faulting has produced a low-lying fault-angle depression into which the Tertiary beds have been lowered, as is illustrated by the diagrammatic section of Fig. 2 in Text.



TEXT-FIG. 2.—Diagrammatic section on the N.N.W.–S.S.E. line A B of Index Map of Faults. XY is the Papakura Valley Fault trending N.E.–S.W. The elevated country to the right represents the northernmost portion of Hunua Range. a: The oldermass. b: The Tertiary covering beds. c: Pleistocene and Recent fluviatile deposits.

It has been shown that the faults of the Papakura-Hunua district form a pattern that is approximately rectangular, in which the main fractures are those of the north-north-west–south-south-east series that are shown by Henderson (1924) to control the structure of the central portion of Auckland Province, diverging from the major north-east–south-west series of the Taupo zone. In a recent paper Henderson applies to New Zealand the view of Bailey Willis that the major faults are due to thrust, and, near the surface, develop steep curved fronts upon the blocks affected, which are tilted away from the frontal fault, whilst in advance there is an area of depression. The facts brought to light by the present investigation do not definitely support this hypothesis, though it may be noted that Bartrum (1926) considers that the continuation of Papakura Valley Fault bends from a east-north-east direction to a northerly one as it passes Clevedon.

As all the faults described have displaced Tertiary beds, they are certainly to be referred to the Kaikoura orogeny of Cotton (1916). There is, however, nothing to show at what date the greater portion of the movements was completed locally. Recent earthquakes in the Morrinsville district indicate that complete stability has not yet been established.

SUMMARY AND CONCLUSION.

The Papakura-Hunua district comprises a broadly truncated surface of folded Mesozoic rocks overlain by a youngermass of

Tertiary age, which evidences minor interruption of deposition at several horizons, though not general unconformity, as postulated by Hutton, between the coal beds near the base of the Tertiary sequence and the overlying Papakura Series.

As a result of important faulting post-dating the deposition of the Tertiary strata, the area is divided into topographic divisions. The central portion is occupied by Hunua Range, a sub-maturely dissected upland block, which on its east, north and west sides is bounded by depressed areas often underlain by Tertiary beds freely mantled by alluvium of Pleistocene and Recent date.

The palaeontological evidence now available is insufficient to enable correlation of the Tertiary strata with stages of the Oamaruian elsewhere to be attempted or an estimate obtained of the relative importance of such indications of minor unconformity as have been observed. So far as local geology is concerned, it is concluded that the Papakura Series represents lower horizons of the Waitemata Series.

APPENDIX.

1. PETROGRAPHY.

(a) *Greywacke of the Hokonui System (? Trias-Jura)* (Fig. 12, Plate 6).

Megascopically the greywackes show some slight variation in grain-size, but, in other respects, samples from different localities agree fairly closely. The mineral grains form a firmly welded equidimensional mosaic with little trace of finer interstitial material. Microscopically they consist of very abundant, decomposed, cloudy feldspar (both orthoclase and plagioclase), a moderate amount of chlorite and subordinate, irregularly shaped, angular grains of quartz. Anhedral fragments of opaque iron-ore (magnetite) are moderately plentiful, whilst there are many scattered granules of epidote. Some samples contain numerous small crystals of green hornblende and a few of augite, often displaying definite crystal outlines. In addition there are sometimes fragments of fine-grained sediment and of various andesites. It is worthy of note that Bartrum (1917, p. 422) reports having found andesitic pebbles in the rocks at Port Waikato which are the uppermost deposits of the Hokonui System.

(b) *Papakura Limestone (Tertiary).* (Fig. 13, Plate 6; Figs. 14 and 15, Plate 7; Fig. 16, Plate 8).

The limestones from Hay's Creek, Ardmore Valley, Bell Creek and from the area north-east of Ardmore Quarry are all essentially similar in texture, in content of calcium carbonate and in their contained organic remains. The great bulk of the rock consists of organic débris cemented by abundant interstitial calcite, whilst there are also small angular grains of quartz and a few of very fine-grained greywacke. Grains of glauconite fill the minute cavities of echinodermal plates (Fig. 15, Plate 7), and other organic material of the limestone at Bell Creek (Fig. 14, Plate 7), and microscopic particles of magnetite occur sparingly in another sample from the same locality.

All the limestones contain some calcareous algae (Fig. 13, Plate 6), but that from the upper part of Bell Creek has them so abundantly that it may be called an algal limestone. In general, however, the Papakura limestone may be more fitly described as a polyzoan limestone, for, with the exception of the algal facies just noted, polyzoa constitute the bulk of the incorporated organic remains (Fig. 16, Plate 8), but there are, in addition to algae and polyzoa, numerous foraminifera with spines and plates of echinoids, corals and occasional fragments of the shells of brachiopods. It thus appears to be closely similar to the polyzoan limestones of Waiwiku Island, Kawhia, and of Gibraltar Rocks, Kaipara Harbour, described by Marshall (1916, p. 91).

(c) *Basalt (Post-Tertiary).*

1. *Boulders on the Western Slopes of Hunua Range.* (Figs. 17, 18, Plate 8).

These boulders litter the western scarp-face of Hunua Range, and are probably the remnants of flows such as those better exhibited further south at Bombay and Pokeno. They are composed of holocrystalline, sub-ophitic rock, in which there are large laths of plagioclase (acid labradorite) partially enwrapped by a somewhat coarse-grained groundmass of abundant irregular crystals or grains of colourless augite. The rock is not markedly porphyritic, though phenocrysts of olivine do occur (Fig. 17, Plate 8), and flow-orientation of the laths of feldspar is lacking. The sections examined show little trace of weathering or alteration, beyond slight serpentinization of the olivine along fractures or the margins. Ilmenite is moderately plentiful in interstitial patches or as occasional rods.

There are numerous small spherulitic masses of radially fibrous calcite, which in places fills the interstices between crystals of the groundmass, so that it is often partially penetrated by laths of feldspar (Fig. 18, Plate 8). The general absence of weathering shows that this calcite cannot have been formed by secondary processes from the rock itself. In addition aggregates of aragonite and other carbonate partially or wholly fill many of the larger vesicles, and it is almost certain that these carbonates and the interstitial calcite of the groundmass have a common origin. Lewis (1912, p. 727) said of zeolites in the Newark igneous rocks of New Jersey that they were formed by magmatic and not meteoric waters, and therefore originated during the final phase of consolidation of the magma, whilst Browne (1923) gave a similar explanation of calcite in basalt at Maitland, N.S.W., and Bartrum (See Ferrar, 1925, pp. 69-70) of carbonates in basalts near Whangarei. There can be no doubt that the carbonates of the boulders near Papakura originate in this manner.

Comparisons with slides of several of the Lower Waikato basalts show that these latter are very similar to that just described.

2. *Basalt from Quarry near the Debouchure of Hay's Creek.*

This rock has a groundmass that is almost pilotaxitic in structure, for it consists largely of exceedingly small, fluxionally arranged laths of plagioclase, which are embedded, along with very numerous

tiny crystals and grains of magnetite and colourless augite, in a small amount of colourless glass. There are abundant, entirely undecomposed, idiomorphic phenocrysts of augite (sometimes schillerized) also olivine and less numerous ones of plagioclase.

2. DESCRIPTION OF COAL BEDS (TERTIARY).

Although not strictly within the area forming the subject of this paper, outcrops in Symond's Stream, a little south of Hay's Creek, and at a coal mine in the Hunua district were examined in the hope that they would assist in the study of the coal measures within the area.

There is a good outcrop in the bed and banks of a small tributary entering Symond's Stream from the north-east, near the bridge on the old Hunua Road. As shown in a drive, the coal is about 3 ft. thick and in parts is a good quality lignite, though towards the bottom of the seam there is admixed fireclay in thin lenses. The "overclay" is about 1 ft. in thickness, and is a very fine-grained sandstone containing some pyrite and broken plant remains and striking N.50°W. with a dip of 70° to the south-west. The "underclay" is a carbonaceous shale, which is exposed for a depth of about 3 ft., though its total thickness could not be ascertained.

Irregularly rounded concretions of ferrous carbonate, partially or wholly oxidized to limonite, are scattered in the bed of the stream. Similar concretions of siderite occur at the Hunua mine, and have been described by Bartrum (1922).

Mr. A. H. Browne, on whose property the coal at Symond's Stream occurs, kindly supplied the following analyses of coal and fireclay which were performed by the Wilson Cement Company:

Coal (Lignite).	
Moisture	18.12
Volatile hydroc.	32.31
Fixed carbon	31.75
Ash	17.82
	100.00
Sulphur	1.97
Fireclay (White).	
Loss on ignition	7.44
Silica	46.94
Alumina	38.12
Oxides of iron	trace
Oxides of zinc	trace
Magnesia	trace
Sulphur trioxide	0.43
Alkalies and undet.	7.07
	100.00

The fireclay has been used with eminent success for the manufacture of fire-bricks.

In the Hunua district, coal crops out in several places close to where it has been mined in recent years on the banks of a small stream flowing north-north-east into Hunua Stream, but the mine alone was closely examined. Here the seam is from 5 ft. to 6 ft. in thickness and has a strike of N.35°W. and a dip of 12° to the north-east. Judged by the material stacked nearby, the coal is a highly friable lignite containing abundant small masses of resin and with films of pyrite in the joint crevices. The overclay is a puce-coloured shale containing the concretions of siderite described by Bartrum (1922) and plentiful impressions of plants, which could be collected only with difficulty owing to the friability of the rock. A little up-stream from the coal, there is an outcrop of fossiliferous marine sandstone, stratigraphically below the coal; this locally has abundant shells of lamellibranchs, though so crushed and decalcified as to be useless for determination.

In Hay's Creek, on the western side of Hunua Range from the coal-mine at Hunua, there are two sets of coaly beds, separated by a fireclay and several feet of sandstone. The upper bed is 2 ft. thick (Fig. 6, Plate 3), and has at its base a one-inch layer of fairly good lignite, whilst the remainder of the bed is highly impure and poorly coherent. The overclay is not visible, but the associated underclay carries abundant impressions of the leaves of dicotyledonous plants, though again collection is exceedingly difficult on account of the fissility and friability of the shale. The lower coaly bed is in reality merely a carbonaceous shale.

In Ardmore Valley the coal was obtained in an old shaft on the property of Mr. Craig. At a depth of 45 ft., an adjacent bore revealed the underlying greywacke, but unfortunately no detailed log is available. In the accessible portion of the shaft the overclay—a typical fireclay—is underlain by a coal bed 1 ft. to 18 ins. deep, in which there is a band 4 ins. in thickness of good brown coal, though the rest of the layer contains much argillaceous impurity. The series of beds dips at 20° to the north-west and contains very imperfect traces of vegetation. It is understood that the bore disposed of all hope of the coal attaining sufficient thickness to be valuable commercially. A chain or so away from the bore, a portion of the same bed appears almost at the level of the adjoining swamp, and, although no fireclays are here in contact with the coal, there are fairly coarse-textured conglomerates apparently little above it.

Hochstetter (1864, pp. 34, 37) referred to the Hunua Coalfield, by which he evidently meant the area mined at Drury, and stated that it was discovered in 1858 by the Rev. Mr. Purchas and worked in the same year. He placed these Drury coals in his Tertiary Brown Coal Formation and obtained from the beds of this formation, at various places nearby, somewhat imperfect leaves determined by Unger as *Myrtifolium lingua*, *Phyllites ficoides*, *P. laurinium*, *P. purchasi*, *P. novae zelandiae*, *Fagus ninnisiana* and *Laranthophyllum dubium*, whilst he also recorded a large bivalve (? *Anodonta*).

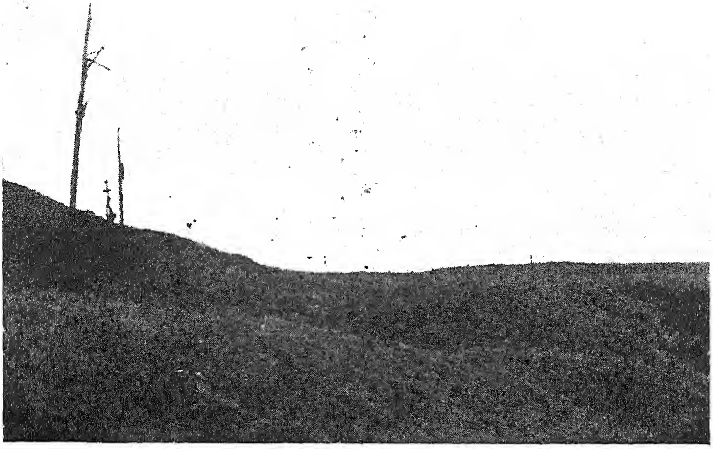


FIG. 1.—Bench topography in Tertiary sandstones on the divide S.E. of the headwaters of Ardmore Stream.

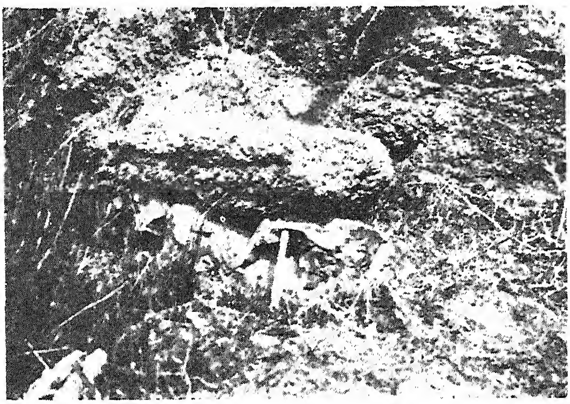


FIG. 2.—The more southerly of the two contacts at Bell Creek showing basal Tertiary conglomerate resting on the eroded surface of the greywacke of the oldermass. [*Photo. by J. A. Bartrum.*

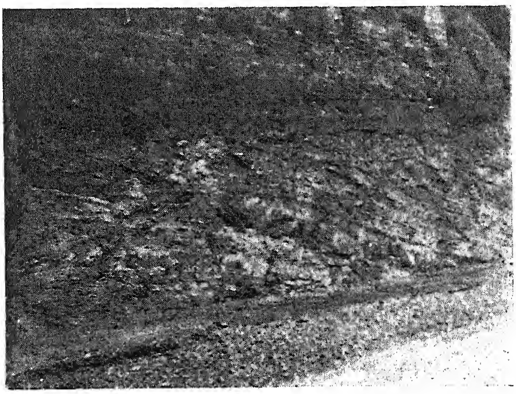


FIG. 3.—Angular unconformity along the roadside about a quarter of a mile E.N.E. of the bridge at the debouchure of Hay's Creek, showing horizontal beds of sandstone resting discordantly on inclined sandstones. [*Photo. by J. A. Bartrum.*

Face p. 64.

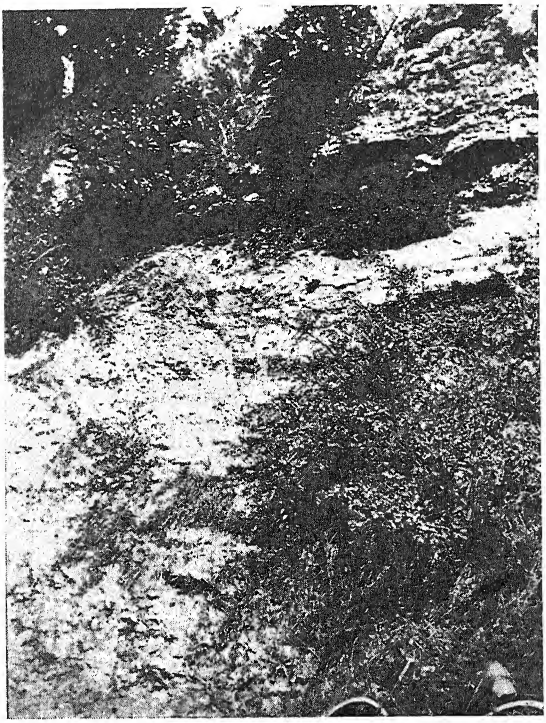


Fig. 4.—Sandstones of the Tertiary along the roadside a few chains east of the debouchure of Hay's Creek, succeeded upwards by a shoreline greywacke conglomerate containing decomposed molluscan and other remains.

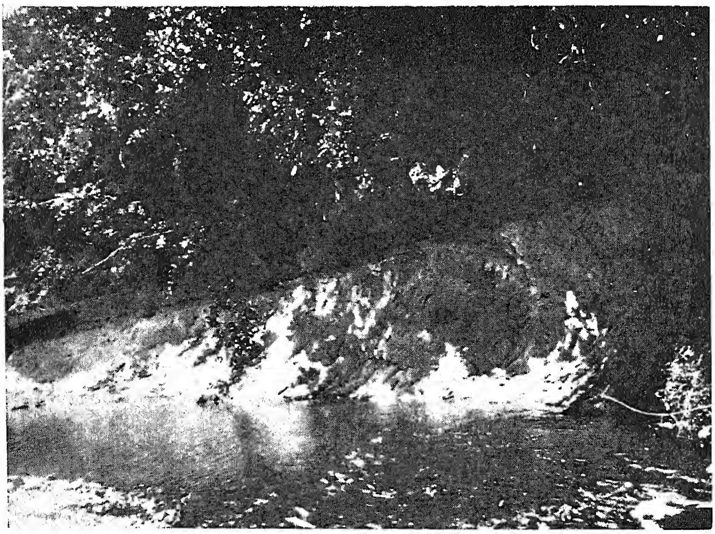


Fig. 5.—The Papakura limestone dipping N.W. and overlying soft greyish-white sandstone, visible from the Papakura-Hunua Road about half a mile east of the debouchure of Hay's Creek.

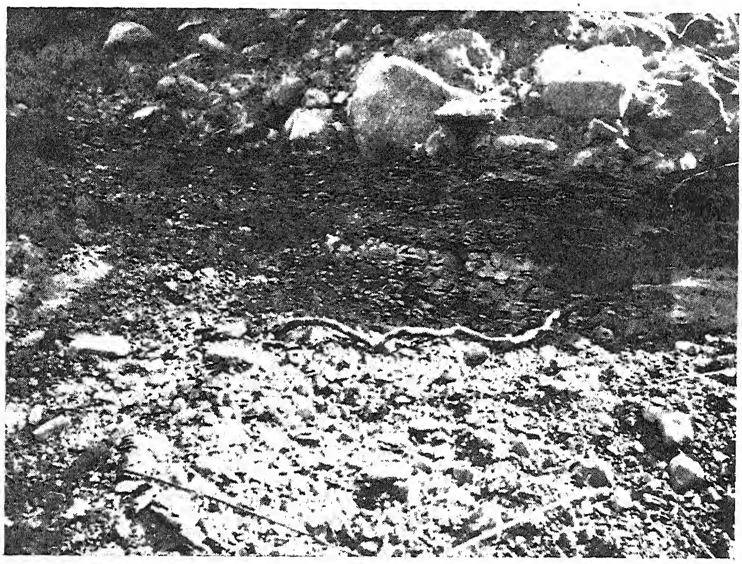


FIG. 6.—The upper coal bed at Hay's Creek overlain by Recent alluvium charged with boulders of greywacke. The underclay is also visible.

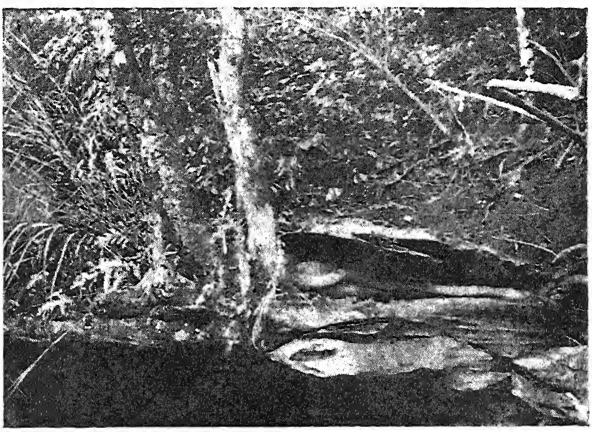


FIG. 7.—Root-wedging in flaggy limestone at Bell Creek, near the more northerly of the two contacts between Mesozoic and Tertiary rocks.

[*Photo. by J. A. Bartrum.*

Fig. 8.—N.W. slopes of Hunua Range. The foreground and right of the picture show a stripped surface of Trias-Jura rocks characteristically closely dissected. The divide in the background consists of Tertiary sandstone, which has slipped and shows the typical hummocky surface caused by such dislocation.

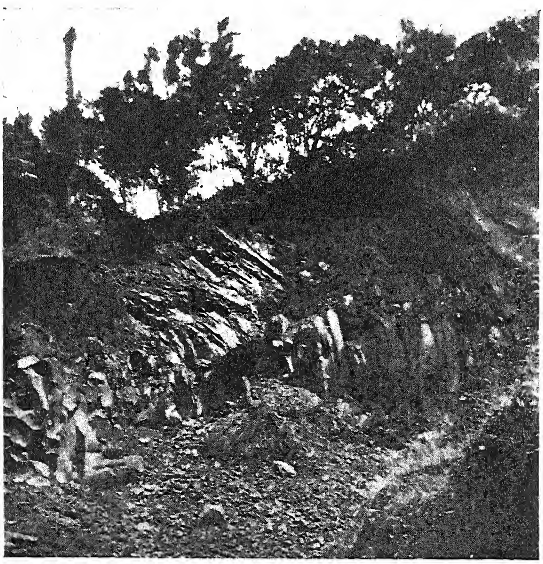


Fig. 9.—Columnar basalt in the quarry near the debouchure of Hay's Creek.

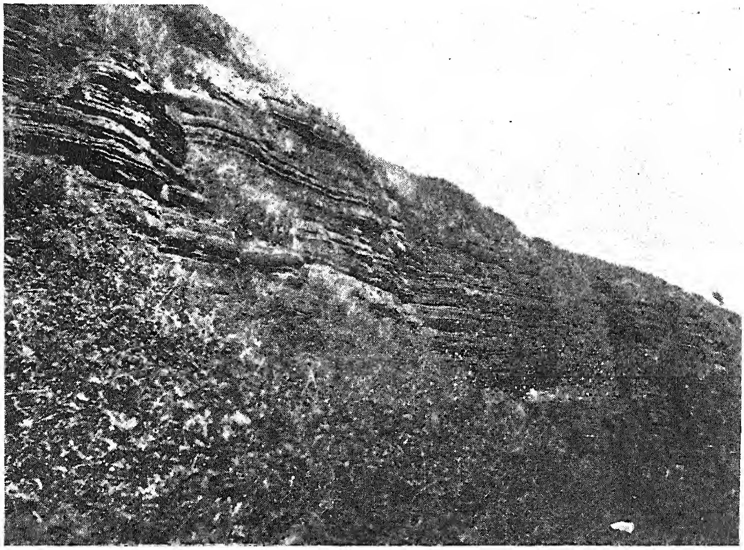


FIG. 10.—Beds of tuff on the divide north of and near the debouchure of Hay's Creek.

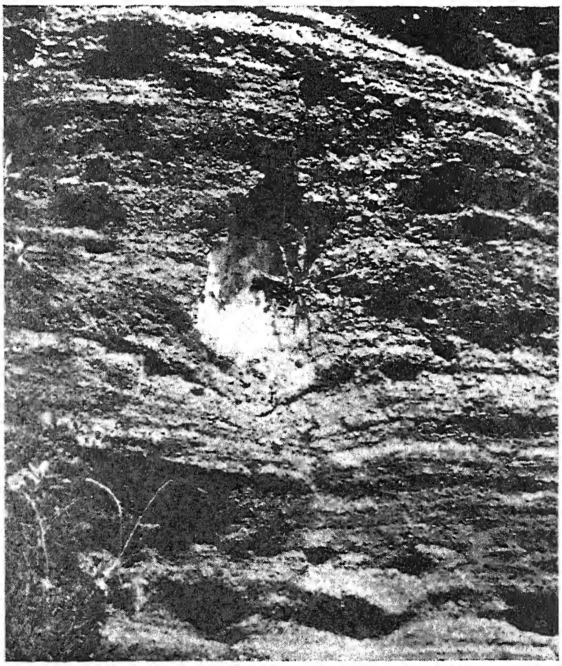


FIG. 11.—A block of Tertiary sandstone causing depression of bedding of the tuffs shown in Fig. 10.

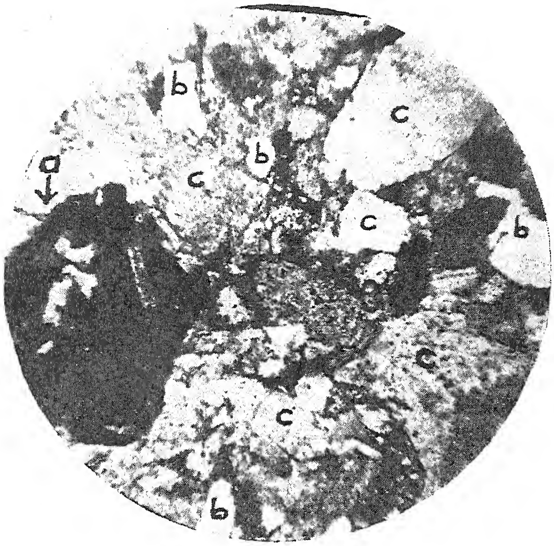


Fig. 12.—Greywacke from Hay's Creek. Fragments of andesite (a), and grains of quartz (b), and of felspar (c) set in a more or less equidimensional mosaic. The remainder of the material comprises chloritised and kaolinised minerals, the original characters of which cannot be determined. Ordinary light. Magnification, 45 diams.

[*Photomicrographs, J. A. Bartrum.*

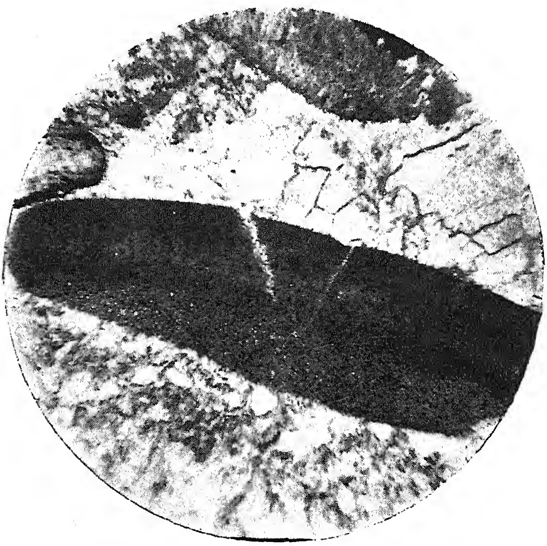


Fig. 13.—Papakura limestone from N.W. slopes of Hunua Range, facing Papakura Valley. Lithothamnium across the centre of the photo, small grains of quartz seen below this and secondary crystalline calcite above. Magnification, 45 diams.

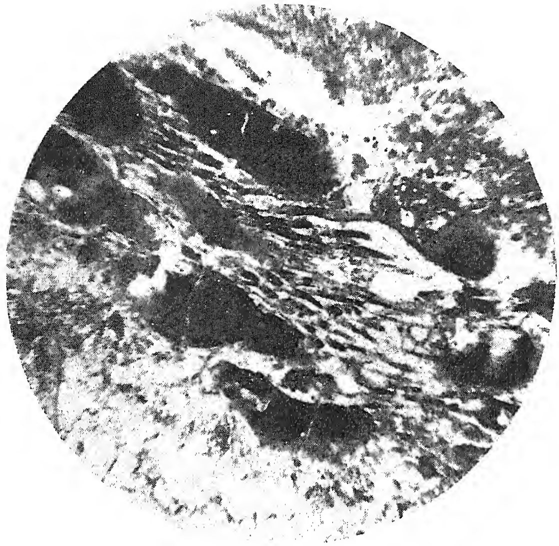


FIG. 14.—Longitudinal section of a polyzoan filled with glauconite. Papakura limestone, Bell Creek. Magnification, 45 diams.

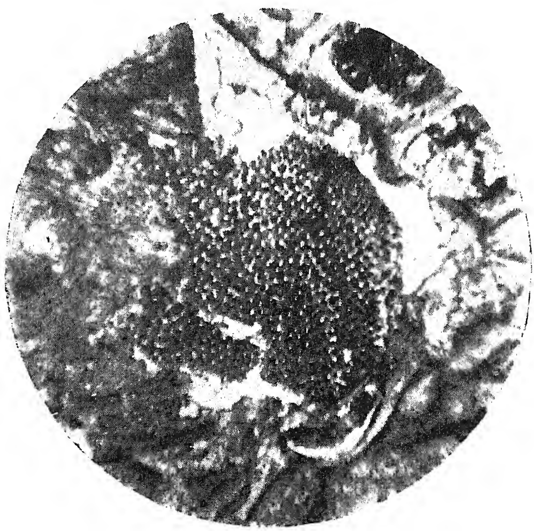


FIG. 15.—Fragment of an echinodermal plate, the interstices filled by grains of glauconite. Papakura limestone, Bell Creek. Magnification, 45 diams.

Fig. 16.—Typical section of Papakura limestone with abundant remains of polyzoa and occasional foraminifera. Magnification, 45 diams.

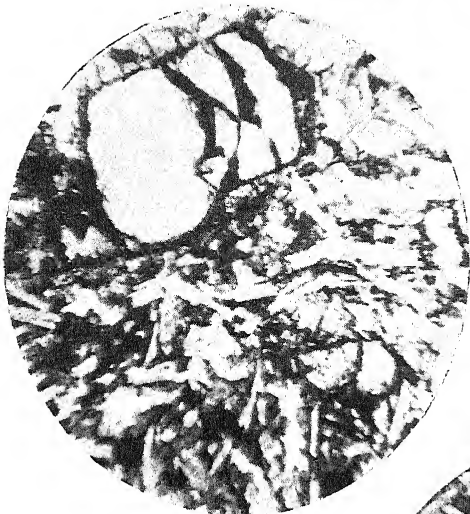


Fig. 17.—Basalt of a boulder on the west flank of Hunua Range. The photograph shows olivine serpentinized along fractures and around borders, laths of felspar (white), and irregular crystals of augite (grey). The black material is partly serpentine and partly rod-like ilmenite. Ordinary light. Magnification, 45 diams.

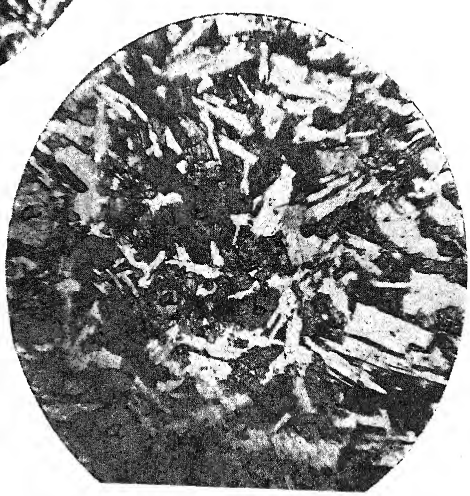


Fig. 18.—Basalt from the same locality as that of Fig. 17, showing irregular crystals of olivine (a), and augite (grey, high relief). Calcite (b) occupies interstices and is partly penetrated by laths of felspar. Ordinary light. Magnification, 45 diams.

The collections examined by von Ettingshausen (1891) do not appear to have included material from this area.

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PART 2, 1931.

ZOOLOGY.

OBITUARY NOTICES.

LIST OF PLATES.

Chemical Determinations of Lime Requirements and their Correlation with Field Response.

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INTRODUCTION.

IN New Zealand, a new country with so much land as yet undeveloped, it is essential that the proper and economical use of fertilisers should be understood. Field experiments with the use of different manures do give the necessary information eventually, but a "hit or miss" method with so many negative results is unscientific, and means in many cases loss of time and money, especially where the results obtained are applicable to only small areas of country. On the other hand, a chemical investigation of the soil, besides determining the problem, should define more readily the area to which it can be applied.

Unfortunately, chemical analyses have very often not given reliable results, and because of this have fallen into bad repute with agriculturalists. Especially has this been so with the liming problem where chemical predictions as to lime response have often been at variance with the field results. Both the agricultural and chemical methods of determining lime response have certain inherent weaknesses. On the agricultural side, tests are made by observation and by hay weights, and the following faults may be noted:—

1. The observation method is liable to a 20% error.

2. Low growing clovers are not cut by the mowers.

3. The Officers of the Agricultural Department have so wide a field to cover that the plots are often not seen at their best time.

4. The types of grasses, etc., are not the same on all plots; and on the same land a red clover response would be more readily measured than one of white clover.

5. The mowing method takes no account of the increase in quality of a pasture.

6. A limiting factor other than lime would prevent a lime response.

On the other hand the chemical evidence is complicated by the hurrying-up process of the laboratory, which seeks to bring about in a few hours changes which would take a year or more in the field; the reagents used are often unnatural ones, and the results obtained are dependent on time of experiment and ratio of soil to solution. It will thus be seen that since lime forms the basis of the most

manurial programmes, a thorough investigation into the connection between chemical tests and field response is necessary. With this object in view some of the best lime-requirement methods have been tested against one another on different soil types where the response to lime had been ascertained by field experiments. In this connection the pH of these soils was measured in the hope that should a correlation exist between lime requirements, pH, and field response, an easy colorimetric method for determining the lime needed would be available for use by the farmers themselves.

Experimental.

The methods of measuring lime in status of the soil can be divided into three classes:—

I. Measurement of lime absorption by the soil:

In these methods a dilute solution of lime in a soluble form is shaken up with a weighed quantity of soil. From the amount absorbed the lime requirement is calculated.

II. Measurement of the available lime in the soil:

These methods aim at determining the amount of lime that can be extracted from the soil by certain reagents. This amount is taken as a measure of lime available for the plant. Apart from the "citric soluble" lime method there is also the replaceable base method wherein the lime is brought into solution by base exchange.

III. Indirect Methods:

These depend upon the changes brought about by the varying lime status of the soils, and do not give a direct measure of lime needed or present, but have to be standardised against the direct methods, pH determinations, active acidity, and the measurement of soluble iron in the Comber test are examples of this type.

Methods.

I. Measurement of lime requirement:

(a) Hutchinson-McLennan (1915). 15 gm. soil, 250 c.c. of ·02 N Calcium bicarbonate, 3 hours' shaking.

As the apparent lime requirement varies with the residual amount of bicarbonate, a correction is made by the method of Crowther and Martin (1925), and the lime requirement is obtained at constant dilution (·015 N.).

(b) Hardy and Lewis (1929). 10 gm. soil, 40 c.c. of ·2 M calcium chloride. Liquor titrated with ·03 N lime water to pH = 7.

II. Replaceable Lime: (Hissink 1923).

Smith's adaptation (1925). —— 25 gm. soil, leached to 500 c.c. with Normal ammonium chloride. Lime precipitated as oxalate and estimated volumetrically by potassium permanganate.

III. Indirect Methods:

(*a*) pH *Electrometric.*
10 gm. soil, 20 c.c. distilled water, sufficient quinhydrone. One minute's shaking and pH determined in usual way, using platinum and gold electrodes.

(*b*) pH *Colorimetric.*
10 gm. soil, 20 c.c. distilled water, stirred for one minute and filtered. To half a test-tube of filtrate four drops of B.D.H. Universal Indicator were added and pH judged.

(*c*) *Replaceable Hydrogen* (Joffe and McLean, 1926).
10 gm. soil leached to three litres with N Barium Chloride. pH of resultant liquor determined, and electrometric titration made to pH = 7 with ·02 N potassium hydroxide. For comparison the figures obtained here have been recalculated in terms of calcium oxide required.

(*d*) *Comber's test for soluble iron.* Carr's modification (1921). 50 gm. soil, 30 c.c. of 4% alcoholic potassium thiocyanate. Titrated with alcoholic hydrochloric acid or potassium hydroxide. For comparison the results have been recalculated as lbs $CaCO_3$/acre.

(*e*) *Truog's test.*
10 gm. soil, 5 c.c. of solution of zinc sulphide suspension in calcium chloride solution and 95 c.c. water.

SAMPLES.

All soil samples have been air-dried, broken down with a wooden roller, and sifted through a 3 mm. sieve.

Information based on hay weights or observations has been supplied with most of the samples. Each number indicates a new soil type—(a) unlimed, (b) limed. Unless otherwise stated, the term " lime " means carbonate of lime. The terms used for describing the soil types are general and not exact.

OTAGO:

I. *Kinnard.* Taieri Plains, near Maungatua.

Eight-year-old pasture in fair condition. Top dressed—1 ton lime 22/7/27. Harvested 18/1/28. Sampled 21/2/29. Hay weights—Control 40·3; limed 46·6. Good response to lime.

II. *Withers.* Foothills of Maungatua.

Ten-year-old pasture that had run out, cocksfoot, sweet vernal, and Yorkshire fog being dominant. 1 ton lime 21/7/27. Harvested 19/1/28. Sampled 21/2/29. Good clover response, but hay weights did not show this up. Hay weights—Control 22·6; limed 22·9.

III. *Spencer.* Taieri Plain, near Contour Channel at Berwick.
Swamp soil. Seven-year-old pasture that had run out. 1 ton lime 29/8/21. Harvested 20/1/28. Sampled 21/7/29. Lime gave a visible response, but mower could not be set low enough to cut the clovers. Hay weights—Control 37·2; limed 37·9.

IV. *Garden soil, University of Dunedin.*

V. *Silt deposited by the Leith Flood in March, 1929, at Dunedin.*

VI. *Borrie.* Papakaio, North Otago.
"Tarry" soil. Response to lime shown by hay weights.

VII. *Green.* Patearoa, Central Otago.
Idaburn stony loam (Ferrar). Drained swamp at foot of irrigated downs. Fifteen-year-old pasture that had run out, large proportion of Yorkshire fog, sweet vernal, and white clover. No response to lime. 1 ton lime 10/8/27. Harvested 15/12/29. Sampled 1929. Hay weights—Control 42·9; limed 41·2.

VIII. *Cratchley.* Kyeburn, Central Otago.
Idaburn stony loam (Ferrar). Old river bed of mica schist gravel now forming a terrace to Kyeburn River. Light loam. Pasture run out to goose grass and gorse. Great response to super, but none to lime. Hay weights—Control 12·6; limed 12·8. 1 ton lime 10/8/29. Harvested 15/12/27. Sampled 1929.

IX. *Kearney.* Ranfurly, Central Otago.
Naseby stony loam (Ferrar). Practically flat land inclined to heaviness, now under irrigation. Twenty-three-year-old pasture, ryegrass and white clover existing in weak condition. Top dressed 1 ton lime 8/8/27. Sampled 1929. No visible response to lime.

X. *Reese.* Berwick.
Swamp soil similar to III. Response to lime.

XI. *Robinson.* Maropuna, South Otago.
1 ton lime August, 1927. Sampled 5/8/29. Lime response on pasture.

XII. *Tweed.* Moneymore, South Otago.
1 ton lime August, 1927. Sampled 5/8/29. No response to lime.

XIII. *Waikouaiti.*
Response to lime.

XIV. *Gore, South Otago.*
Potash response, but no information yet re lime.

XV. *Repeat Sample on XI.*
Sample taken from different parts of the field. Sampled October, 1929.

NELSON:

XVI. *Pakihi lands, West Coast.*

Lime and phosphate are limiting factors. Burnt and topdressed in 1928 with two tons slaked lime and ten cwt. basic slag.

XVII. *Anderson.* Riwaka.

Untreated fine sand, used in peach experiments for last four years. Very well supplied with phosphates. Ideal soil for peaches, raspberries, and tobacco.

XVIII. *Fry.* Riwaka.

Good pasture on coarse sand loam, derived mainly from hornblende granite wash. This pasture, which is high in phosphates, has not been treated for 40 years.

XIX. *Mildura.* Alongside Sunrise Valley road.

Moutere Hills type. Markedly deficient in lime and phosphate. Responds wonderfully to lime. Control had super alone. Limed—two tons 1922 and 24 cwt. / acre in March, 1926.

XX. *Mildura.* Near Sunrise Valley road.

Control 5 cwt. of basic slag in 1922. Limed—2 tons limestone and 5cwt. superphosphate in 1922. Good response to lime.

XXI. *Saxton.* Stoke.

Limed—1 ton per acre. Good response to lime over Control and super alone. (a) Control; (b) Limed; (c) Super alone; (d) fine lime + super; (e) Coarse lime + super.

SOUTHLAND:

XXII. *Udy.* Wyndham.

Heavy soil; (a) good turnip land; (b) excellent pasture.

XXIII. *Morton Mains.*

Good response to lime. Sheep mortality higher than in surrounding districts.

XXIV. *Clark.* Tussock Downs.

Good heavy country. Response to lime.

SOUTH CANTERBURY:

XXV. *Gillingham.* Cave.

Medium clay downs. No observed response to lime. 1 ton lime 13/6/28. Sampled 26/8/29.

XXVI. *Cleland.* Upper Totara Valley.

Good warm clay downs. Observational plot. Excellent response in red clover due to lime. 1 ton lime 23/8/28. Sampled 27/8/29.

XXVII. *Orbell.* Levels.

Medium clay downs. Observational plot. Slight response to lime. 1 ton lime 29/6/28. Sampled 28/8/29.

XXVIII. *Talbot.* Claremont.

Cold clay downs. Observational plot. Excellent response in red clover. 1 ton lime 22/6/28. Sampled 28/8/29.

XXIX. *Paterson.* Temuka.

Sandy loam with stiff clay bottom. Results expressed as hay weights. Marked response to lime both in 1927 and 1928. Limed 25cwt. 19/7/27, 20cwt. 2/7/28. Sampled 4/9/29.

XXX. *Oakley.* Albury.

Medium clay downs. Observational plot. Slight response to lime. 1 ton lime 6/7/28. Sampled 27/7/29.

XXXI. *Black.* Salisbury.

Cold clay downs. Observational plot. Response to lime. 1 ton lime 20/7/28. Sampled 18/10/29.

XXXII. *Kelland.* Fairview.

Medium clay downs. Observational plot. Limed 1 ton 20/7/28. Sampled 18/10/29. Improvement due to lime.

XXXIII. *Orbell.* Rosewill.

Warm clay downs. Definite response to lime. 1 ton lime 3/7/28. Sampled 18/10/29.

XXXIV. *Brosnahan.* Seadown.

Coastal area. Good loam. Slight improvement due to lime. 1 ton lime 21/6/28. Sampled 18/10/29.

NORTH CANTERBURY:

XXXV. *McMullan.* Kaiapoi.

No marked response to lime. Pasture sown with wheat in 1927. 1 ton lime 20/7/28. Sampled 13/9/29.

XXXVI. *Morgan Williams.* Kaiapoi.

No marked response to lime. Peaty soil overlying fairly heavy silty clay. Old grassland. 1 ton lime 20/7/28. Sampled 13/9/29.

XXXVII. *Cross.** Oxford.

Very good response to lime. Pasture sown down with oats September, 1927. Natural drainage excessive. Light silty loam over clay and shingle. 1 ton lime 3/8/28. Sampled 17/9/29.

XXXVIII. *Skurr.* Oxford.

Good response to lime. Down in pasture at least 12 years. Heavy clay loam overlying heavy clay subsoil. 1 ton lime 3/8/28. Sampled 17/9/29.

MID-CANTERBURY:

XXXIX. *Morris.* Winchmore.

Stony medium plains. Pasture two years old, consisting of ryegrass, cocksfoot, fog, and clovers. Slight response to lime. Limed 1 ton 18/8/28. Sampled 2/8/29.

XL. *Bonnington.* Riverside.

Stony medium plains. Two-year-old pasture composed of ryegrass, brown top, yarrow, ribgrass, and clovers. Response to lime. Limed 1 ton 18/7/28. Sampled 5/8/29.

XLI. *Stewart.* Rakaia.

Heavy land on terrace adjoining Rakaia River. Silty formation. Pasture two years old, composed of ryegrass, twitches, fog, and clovers. Response to lime. 1 ton lime 26/7/28. Sampled 30/7/29.

XLII. *Bonifant.* Wakanui.

Medium land. Two-year-old pasture—twitches, ryegrass, fog, and clovers. Lime response. 1 ton lime 18/7/28. Sampled 5/8/29.

XLIII. *Goodwin.* Lauriston.

Medium soil. Pasture one year old, composed of ryegrass, goosegrass, twitches, and clover. Strong lime response. 1 ton lime 18/8/28. Sampled 2/8/29.

XLIV. *Wilson.* Dromore.

Stony plains. Sown down with rape in November, 1928. Showing response 27 days after liming. Pasture brown top, ryegrass, red and white clovers. 1 ton lime 3/7/29. Sampled 30/7/29.

Table.—Column 4 gives the Hutchinson-McLennan lime requirement determined in the ordinary way, while column 5 gives the figure corrected to ·015 N. dilution. From the figures in column 5 the amount of CaO present has been calculated (column 6) for comparison with other lime requirement methods and replaceable lime (13). Columns 7 and 8 are derived from the two other methods of determining lime requirement, while column 9 figures are from the Comber test. In columns 10, 11, and 12 the pH figures are compared, and in 14, 15, 16 the ratios from lime requirements and replaceable lime. Column 17 gives a rough measure of the capacity of the soil for lime—the amount of lime available if the soil were fully saturated.

Although not shown in the table the active acidity has been measured by the method of Truog, and the pH determined colorimetrically using B.D.H. Universal Indicator. The results of both these methods followed closely the electrometrically measured pH, and distinguished between soils at intervals of ·5 pH.

			LIME REQUIREMENT METHODS						pH			CaO Replac.	RATIOS			Capacity
			CaCO 3		CaO											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SAMPLE	DESCRIPTION	RESPONSE TO LIME	Lime Reqm. as found CaCO 3%	Lime Reqm. (4) corrected CaCO 3%	(5) Recal. as CaO %	CaO Reqm. cal. from Replac. H	CaO reqd. to titrate to pH = 7	Comber Test. lbs. CaCO 3 per acre	pH on aq. extr.	pH on BaCl 2 extr.	pH on CaCl 2 extr.	Replac. Lime CaO%	CaO Reqd. (6) / CaO Replac. (13)	CaO Reqd. (7) / CaO Replac. (13)	CaO Reqd. (8) / CaO Replac. (13)	Sum Replac. CaO (13) / CaO Reqd. (6)
I	a	Yes	.37	.36	.20	.14	—	2200	5.8	4.9	—	.16	1.3	.9	—	.36
	b		.27	.26	.14	.11	—	1850	6.0	5.1	—	.17	.9	.7	—	.31
II	a	Yes	.27	.26	.14	.12	—	1900	5.8	4.9	—	.16	.9	.8	—	.30
	b		.24	.23	.13	.10	—	1770	5.9	5.1	—	.17	.8	.6	—	.30
III	a	Yes	.68	.76	.42	.29	—	5460	4.7	4.6	—	.28	1.5	1.0	—	.69
	b		.68	.76	.42	.25	—	5050	4.8	4.7	—	.31	1.3	.8	—	.73
IV			.15	.13	.07	.04	—	890	7.2	5.8	—	.62	.1	.06	—	.70
V			.06	.05	.03	.03	—	4070	6.8	5.8	—	.49	.06	.06	—	.52
VI	a	Yes	.18	.16	.09	.06	—	1010	6.2	5.3	—	.55	.2	.1	—	.64
	b		.08	.07	.04	.03	—	260	6.7	6.2	—	.46	.09	.07	—	.50
VII	a	No	.01	.01	.004	.04	—	90	7.7	5.8	—	.29	.01	.1	—	.29
	b		.04	—	—	—	—	20	7.9	—	—	.28	—	—	—	—
VIII	a	No	.02	.02	.01	.05	—	260	6.8	5.4	—	.29	.04	.2	—	.30
	b		.03	.03	.01	.05	—	220	6.6	5.4	—	.30	.04	.2	—	.31
IX	a	No	—	—	—	.06	—	410	7.0	5.5	—	.19	—	.3	—	.19
	b		.02	.02	.01	.05	—	410	6.5	5.7	—	.18	.05	.3	—	.19
X	a	Yes	.66	.72	.41	.29	.49	6970	4.9	4.8	4.3	.24	1.7	1.2	2.0	.65
	b		.65	.70	.40	.29	—	5940	4.9	4.7	—	.26	1.5	1.1	—	.65
XI	a	Yes	.07	.06	.04	—	.07	—	6.3	—	5.3	.26	.1	—	.3	.30
	b		.12	.11	.06	—	.12	—	5.3	—	4.8	.19	.4	—	.6	.25
XII	a	No	.07	.06	.03	—	.07	—	6.4	—	5.4	.20	.2	—	.4	.23
	b		—	—	—	—	.12	—	5.6	—	4.7	.13	—	—	.9	—
XIII	a	Yes	.24	.23	.13	—	.17	—	5.4	—	4.6	.12	1.0	—	1.4	.25
	b		—	—	—	—	.16	—	5.6	—	4.6	.14	—	—	1.1	—
XIV	a		.27	.24	.13	—	—	—	5.3	—	—	.16	.8	—	—	.30
XV	a	Yes	.13	.11	.06	—	—	—	5.9	—	—	.22	.3	—	—	.28
	b		.13	.11	.06	—	—	—	5.5	—	—	.18	.3	—	—	.24

			LIME REQUIREMENT METHODS										CaO Replac.	RATIOS			Capacity
			CaCO 3		CaO				pH							
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SAMPLE	DESCRIPTION	RESPONSE TO LIME	Lime Reqm. as found CaCO 3%	Lime Reqm. (4) corrected CaCO 3%	(5) Recal. as CaO %	CaO Reqm. cal. from Replac. H	CaO reqd. to titrate to pH = 7	Comber Test. lbs. CaCO 3 per acre	pH on aq. extr.	pH on BaCl 2 extr.	pH on CaCl 2 extr.	Replac. Lime CaO%	CaO Reqd. (6) / CaO Replac. (13)	CaO Reqd. (7) / CaO Replac. (13)	CaO Reqd. (8) / CaO Replac. (13)	Sum Replac. CaO (13) CaO Reqd. (6)
XVI	a	Yes	.47	.48	.27	.31	—	5710	4.4	4.2	—	0	—	—	—	.27
	b		.39	.39	.22	.25	—	3620	5.2	4.7	—	.21	1.0	1.2	—	.43
XVII		No	.09	.08	.05	.09	—	1770	6.2	5.1	—	.13	.4	.7	—	.18
XVIII			.35	.34	.19	.20	—	4930	5.5	4.8	—	.15	1.2	1.3	—	.34
XIX	a	Yes	.31	.30	.17	.24	—	6280	5.2	4.9	—	.02	7.0	12.0	—	.19
	b		.17	.15	.09	.14	.12	3650	5.6	5.5	4.5	.09	1.0	1.6	1.3	.17
XX	a	Yes	.18	.17	.10	.13	.16	3480	5.3	4.9	4.4	.03	3.3	4.3	5.3	.12
	b		.10	.09	.05	.09	.07	1980	6.0	5.0	4.8	.14	.4	.6	.5	.19
XXI	a	Yes	.24	.23	.13	.17	.16	3620	5.8	4.9	4.5	.08	1.5	2.1	2.0	.21
	b		.20	.19	.12	.13	—	2340	5.9	5.1	—	.11	1.4	1.2	—	.21
	c	Yes	.23	.22	.10	.16	—	3790	5.7	4.9	—	.09	.9	1.8	—	.21
	d		.13	.12	.07	.09	.08	2070	6.2	5.5	5.0	.16	.4	.6	.5	.22
	e		.19	.17	.10	.13	.14	2020	5.7	5.3	4.7	.13	.7	1.0	1.1	.23
XXII	a		—	—	—	—	.14	—	—	—	4.9	.21	—	—	.7	—
	b		—	—	—	—	.16	—	—	—	4.9	.12	—	—	1.3	—
XXIII		Yes	—	—	—	—	.23	—	—	—	4.5	trace	—	—	—	—
XXIV		Yes	—	—	—	—	.20	—	—	—	4.5	.06	—	—	3.3	—
XXV	a	No	.17	.15	.08	—	—	—	5.8	—	—	.15	.6	—	—	.24
XXVI	a	Yes	.24	.22	.12	—	—	—	5.2	—	—	.12	1.0	—	—	.34
	b		.19	.17	.09	—	—	—	5.7	—	—	.16	.5	—	—	.25
XXVII	a	Yes	.25	.22	.13	—	—	—	5.3	—	—	.12	1.1	—	—	.24
	b		.22	.20	.11	—	—	—	6.0	—	—	.16	.6	—	—	.27
XXVIII	a	Yes	.29	.26	.15	—	—	—	5.5	—	—	.10	1.4	—	—	.25
XXIX	a	Yes	.32	.29	.17	—	—	—	5.2	—	—	.14	1.2	—	—	.31
	b		.19	.17	.10	—	—	—	6.1	—	—	.27	.4	—	—	.36
XXX	a	Yes	.48	.46	.26	—	—	—	4.6	—	—	.04	6.9	—	—	.29
	b		.40	.37	.21	—	—	—	4.9	—	—	.13	1.5	—	—	.34

			LIME REQUIREMENT METHODS						pH			CaO Replac.	RATIOS			Capacity
			CaCO 3		CaO											
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
SAMPLE	DESCRIPTION	RESPONSE TO LIME	Lime Reqm. as found CaCO 3%	Lime Reqm. (4) corrected CaCO 3%	(5) Recal. as CaO %	CaO Reqm. cal. from Replac. H	CaO reqd. to titrate to pH = 7	Comber Test. lbs. CaCO 3 per acre	pH on aq. extr.	pH on BaCl 2 extr.	pH on CaCl 2 extr.	Replac. Lime CaO%	CaO Reqd. (6) / CaO Replac. (13)	CaO Reqd. (7) / CaO Replac. (13)	CaO Reqd. (8) / CaO Replac. (13)	Sum Replac. CaO (13) CaO Reqd. (6)
XXXI	a	Yes	.21	.18	.10	—	—	—	5.7	—	—	.09	1.2	—	—	.19
XXXII	a	Yes	.25	.23	.13	—	—	—	6.1	—	—	.11	1.1	—	—	.14
XXXIII	a	Yes	.22	.20	.11	—	—	—	6.1	—	—	.15	.7	—	—	.25
XXXIV	a	Yes	.23	.20	.11	—	—	—	5.8	—	—	.10	1.1	—	—	.21
XXXV	a	No	.15	.13	.07	—	—	—	6.0	—	—	.24	.3	—	—	.31
XXXVI	a	No	.36	.33	.19	—	—	—	5.7	—	—	.29	.6	—	—	.47
XXXVII	a	Yes	.44	.42	.24	—	—	—	4.9	—	—	.05	4.9	—	—	.29
XXXVIII	a	Yes	.28	.25	.14	—	—	—	5.3	—	—	.11	1.4	—	—	.25
XXXIX	a	Yes	.27	.25	.14	—	—	—	5.5	—	—	.12	1.0	—	—	.26
XL	a	Yes	.19	.16	.09	—	—	—	5.8	—	—	.09	1.1	—	—	.18
XLI	a	Yes	.16	.14	.08	—	—	—	5.8	—	—	.10	.8	—	—	.18
XLII	a	Yes	.18	.15	.09	—	—	—	5.6	—	—	.09	.9	—	—	.18
XLIII	a	Yes	.24	.21	.12	—	—	—	5.3	—	—	.09	1.4	—	—	.21
XLIV	a	Yes	.22	.19	.11	—	—	—	5.4	—	—	.06	1.9	—	—	.17

Practically all the soils behaved normally in that the process of liming decreased the lime requirement, and increased the pH and replaceable lime. Three soils, however, showed abnormal features.

1.—VI, where the application of lime had apparently decreased the replaceable lime on the limed plots compared with the Controls.

2.—XI, duplicated by XV, where the application of lime had decreased the replaceable lime and pH, and increased the lime requirement as shown by two different methods. In both these soils (VI, XI, XV) the Agricultural report on the response obtained was at variance with the predictions of all the chemical tests.

3.—XII, where the application had decreased the replaceable lime and pH, and increased the lime requirement. The Agricultural report agreed with the predictions of the chemical analyses.

Although the cores collected to make the samples, and the analyses made on them were sufficiently numerous to make the results reliable, in view of the possibility of there being an error in the field work, it was thought advisable to neglect these in drawing general conclusions.

CONCLUSIONS.

The general correlations between field response and chemical tests are given below. The soils examined are classified into two groups:—

A. Sufficient soils have been examined by the methods of this group to make results reliable.

B. A limited number of soils have been examined by the remaining methods and only approximate conclusions can be drawn. The methods used for this examination compared less favourably with those used in Group A.

A. (1) Lime requirement ($CaCO_3$) Hutchinson-McLennan.

Response to lime > (·17—·18%) > No response to lime. Two exceptions in 38 soils.

(2) Replaceable lime (CaO).

No response to lime > ·25% > Response to lime. Five exceptions in 40 soils.

(3) pH Value (electrometric).

No response to lime > (5·8-5·9) > Response to lime. Five exceptions in 38 soils.

(4) Ratio given by $\frac{\text{CaO required}}{\text{CaO replaceable}}$. (From Hutchinson-McLennan corrected figure).

Response to lime > (·5—·6) > No response to lime. No exceptions in 38 soils.

B. (1) Comber test. Eight soils.

Response to lime > (approx. 1000lb $CaCO_3$ /acre).
> No response to lime.

(2) Lime requirement CaO (Hardy and Lewis). Eight soils.

a. Original pH < pH = 5·4. Response to lime.

b. Lime requirement (CaO) > ·16%. Response to lime.

c. Ratio $\left\{\dfrac{\text{CaO required}}{\text{CaO replaceable.}}\right.$

Response to lime > 1·0 > No response to lime.

(3) Lime requirement ($BaCl_2$ extract). Fourteen soils.

a. Original pH.
No response to lime > (pH = 5·1) > Response to lime.

b. Lime requirement (CaO).
Response to lime > ·09% > No response to lime.

c. Ratio $\left\{\dfrac{\text{CaO required}}{\text{CaO replaceable.}}\right.$

Response to lime > ·7 > No response to lime.

GENERAL:

1. Comparison of values given by lime requirements (CaO) from three methods.

   A1 : B3B : B2b : = 1 : 1·2 : 1·5.

2. Between the lime requirement and pH methods there is only a rough correlation.

3. The approximate capacity for lime (column 17) indicates to what extent the ratio $\left\{\dfrac{\text{CaO required}}{\text{CaO replaceable}}\right.$ will change between the limed and unlimed samples. A low figure indicates a big, and a high figure a small change.

4. No conclusions could be drawn as to the effect of one ton of lime ($CaCO_3$) on the constants obtained for the soil before and after liming, since variable factors such as time, climate, drainage, etc., could not be eliminated.

SUMMARY.

The various methods of attack give general indications of the field response to be expected, but they break down in certain cases. Of the direct lime requirement methods, the Hutchinson-McLennan method combines most satisfactorily accuracy with convenience, and since it measures the immediate lime absorption, it is likely to be more comparable with field conditions than the replaceable hydrogen methods (Hardy-Lewis, etc.) which, no doubt, give the ultimate absorption. The Hardy-Turner method suffers from the defect that the readings obtained are a function of the shaking. On the other hand these methods of electrometric titration to pH = 7 give useful curves showing the buffer action of the soil.

The work indicates that no single factor determination gives satisfactory evidence of field response. Since the acidity is caused by the hydrogen iron, and since lime can ameliorate its effect by reducing acidity, precipitating toxic iron, alumina (possibly), and manganese, liberating phosphates, flocculating clays and promoting bacterial activity, it is reasonable to suppose that the ratio H^+ to Ca^{++} indicates the soil status with regard to lime. (Compare Hissink l.c.) Saturation value $V = \frac{100S}{T}$; Comber, ratio $\frac{\text{absorbed lime}}{\text{max. lime requirement.}}$ The ratio adopted here $\left\{ \frac{\text{CaO required (H. McL.)}}{\text{-CaO replaceable}} \right.$ has been compared with field response and a good correlation has been obtained for these normal South Island soils. Where the old method of interpreting the Hutchinson-McLennan lime requirement figure in terms of $\cdot 1\% = 1$ ton $CaCO_3$ /acre failed was in not realising that as the lime requirement was reduced by liming, the replaceable lime was increased, with the consequence that only a portion of that lime requirement had to be satisfied for optimum soil conditions. The ratio method takes full account of this factor. An advantage of this method is that it is practically independent of the moisture and gravel content of the soil since it is derived from two percentages determined at the same time.

The correlation between laboratory methods and field results must remain at the moment qualitative rather than quantitative, since the agricultural evidence on the effect of lime is based on methods that do not give quantitative results. Until more reliable field trials —such as sheep weights—are introduced, a more rigid examination cannot be made of the chemical methods.

My sincere thanks are due to Dr J. K. H. Inglis, in whose Department this work was done, for his interest and help throughout the investigation. I am indebted to Mr T. Rigg, of the Cawthron Institute, for literature and arranging for samples; to Mr A. W. Hudson, of the Plant Research Station, for arranging for the collection of samples; to Messrs Tennent, Hume, Selwood, Wallace, Calder, Bates, A. Y. Montgomery, and K. Montgomery, of the Department of Agriculture; and Mr G. A. Holmes, of the National Mortgage Co., for arranging for or collecting samples, and supplying information concerning them. Without their co-operation this work would not have been possible. Acknowledgments are due to the Department of Scientific and Industrial Research for a grant for travelling expenses.

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Three New Tertiary Gastropods.

By L. C. King, M.Sc.

[*Read before Wellington Philosophical Society, 13th August, 1930; received by Editor, 7th August, 1930; issued separately, 30th September, 1931.*]

Of the three new gastropods described below, two from Callaghan's, Greymouth, were discovered in the Victoria College Collection, and were probably collected by the late Mr. P. G. Morgan during his study of the Greymouth Subdivision. The remaining species from Hurupi Creek, Palliser Bay, was sent to the writer in a large collection of fossils from that locality for which he is indebted to Mr. Colin Campbell, after whom the new species is named. The writer's thanks are also tendered to Mr. W. H. A. Penseler for the care he took in photographing the specimens.

Bolma colini, n. sp. Figs. 1-3.

Shell large, turbinate, solid, imperforate. Protoconch broken in the type specimens. Whorls four, angulate, with a gently sloping shoulder surmounted by strong tubercles. Sculpture consisting of strong tubercles on the shoulder angle, 9 to 11 on the spire-whorls, 8 on the body-whorl. Below the suture is a row of oblique, strong rounded tubercles, becoming weaker and finally dying out on the body-whorl. Between this and the shoulder-angle are two weak nodular cords, the nodules on later whorls becoming detached and finally obsolete. On the side of the spire-whorls are two weakly nodular spiral cords, the lower one much the stronger. A third weak spiral appears from the suture on the body-whorl. Following the line of suture on the body-whorl is a line of strong rounded tubercles forming a well defined keel. On the base are eight irregular nodular cords. The inner margin of the base bounding the aperture has three very strong round tuberculate knobs. The surface is covered with fine spiral threads crossed by well-marked, regular growth-ridges. Aperture circular, interior nacreous. Outer lip probably sharp. Columella concave, with a shallow groove developing towards its anterior end. Inner lip spreading well over the umbilical area.

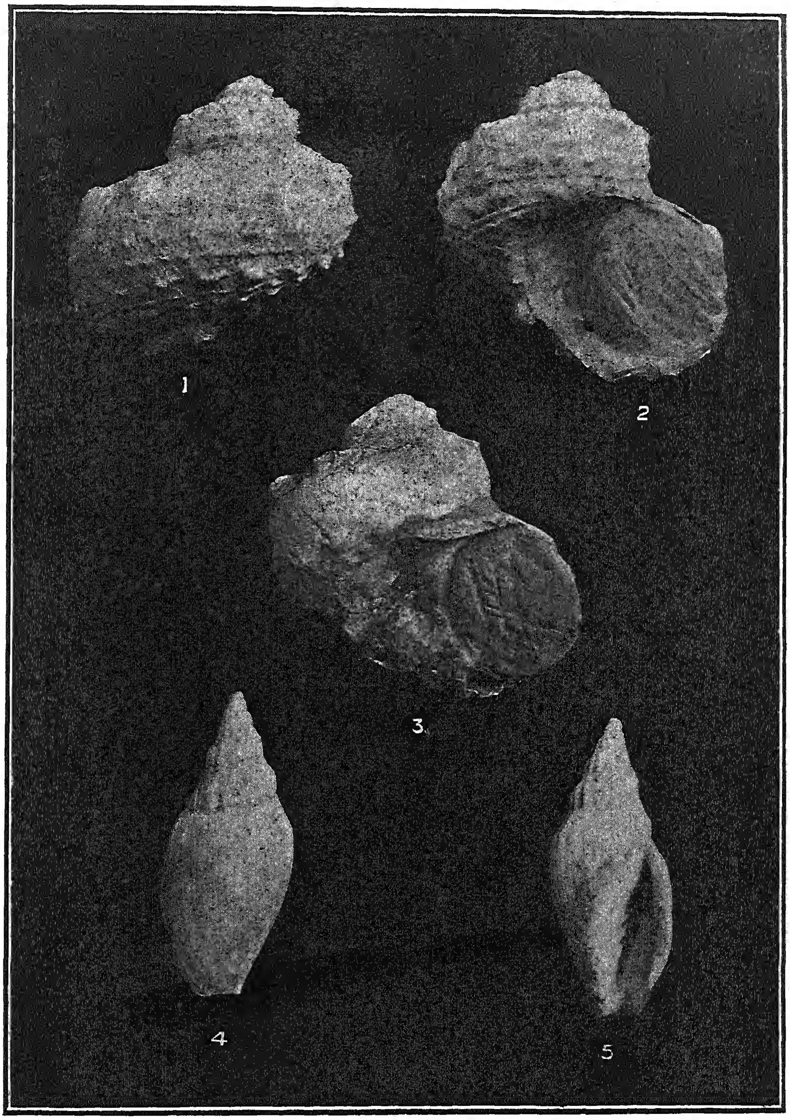
Locality.—Hurupi Creek, Palliser Bay.

Height, 80 mm.; diameter, 84 mm.

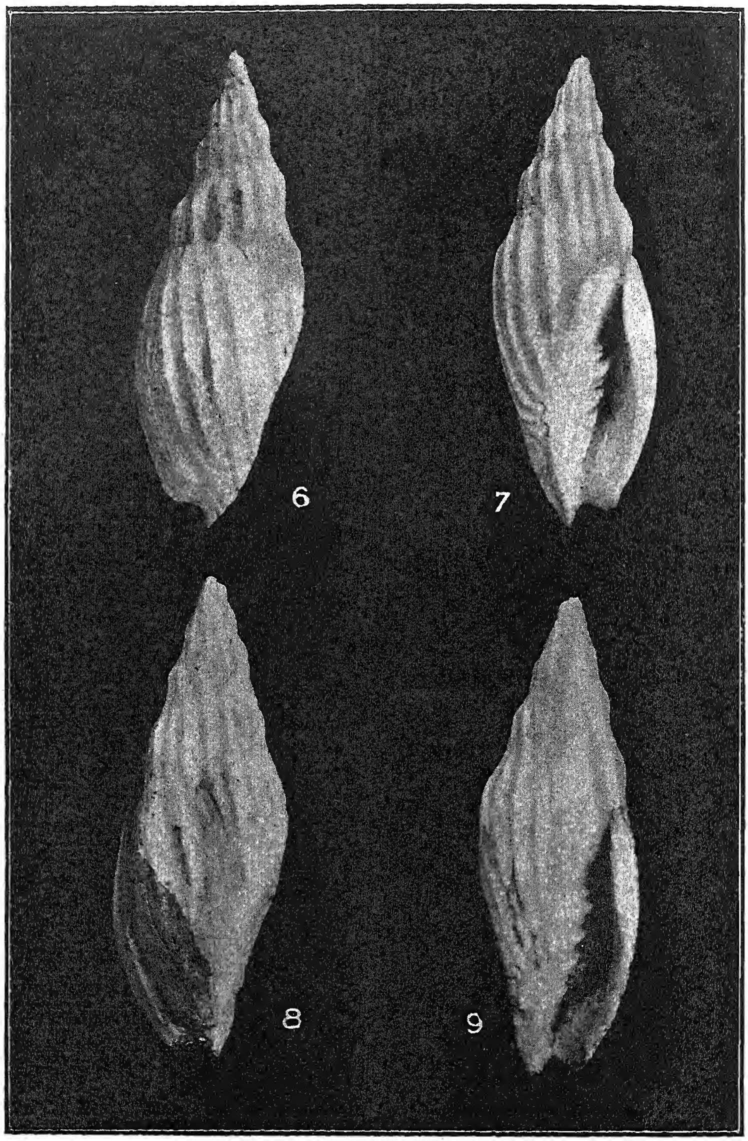
Holotype presented to the Collection of the New Zealand Geological Survey.

This species is a close relative of *Turbo superbus* Zittel, but it has additional spirals, and the tubercles on the sides and shoulder-angle are not so strongly marked. There are also three very strong tubercles on the basal margin of the aperture.

Bolma was proposed by Risso in 1826, with *Turbo rugosus* Linné as monotype. Chenu, Manuel de Conchyliologie, Vol. 1, p. 351, figured this and also *Turbo gibberosus* Gmelin. Unfortunately, his figures are reversed, as shown by specimens of *T. rugosus* in the collection of the New Zealand Geological Survey, and the figures of Cossmann and Zittel. *T. gibberosus* in any case seems to have lapsed into synonymy or have been originally a nomen nudum. The New



FIGS. 1 and 2.—*Bolma colini* n. sp. Holotype.
FIG. 3.—*Bolma colini* n. sp. Paratype.
FIGS. 4 and 5.—*Pachymelon callaghani* n. sp. Holotype.



FIGS. 6 and 7.—*Alcithoe gravicostata* n. sp. Holotype.
FIGS. 8 and 9.—*Alcithoe gravicostata* n. sp. Paratype.

Zealand shell may prove to be generically separable from true *Bolma*, but until specimens showing protoconch and complete aperture are available it is left in the European genus.

Pachymelon callaghani, n. sp. Figs. 4, 5.

Shell of moderate size, thick, fusiform. Spire about two-thirds the height of the aperture. Post-embryonic whorls 5, slightly convex with a lightly developed shoulder; body-whorl somewhat inflated. Sculpture of axial ribs, with about equal concave interspaces, 14 on the pen ultimate whorl, but quickly becoming obsolete on the body-whorl. Fasciole concave, plainly marked but not sharply defined from the base of the body-whorl. Aperture narrow, lightly channelled above, and slightly sinused below. Outer lip convex, thick, somewhat reflexed. Columella with three strong plaits and one weaker anterior plait. Inner lip thick, with a sharply defined arcuate outer edge, spreading well across the body-whorl.

Height, 60 mm.; diameter, 26 mm.

Locality.—Callaghan's, Stafford Town, Greymouth.

Holotype presented to the Collection of the New Zealand Geological Survey.

This species resembles *P. renwicki* Marwick, from the Chathams, but differs in the more convex spire-whorls and the better developed shoulder.

Since the above description was written, twelve specimens very closely resembling the type were obtained from the cliffs east of Lake Ferry, Wairarapa. They were all rather frailer shells, and exhibited a somewhat lower spire and slightly deeper anterior notch than the type.

Alcithoe gravicostata, n. sp. Figs. 6-9.

Shell of medium size, thick, strong. Spire turreted, slightly shorter than the aperture; spire-whorls with a sloping, strongly angled shoulder. Sculpture of heavy axial ribs, with about equal concave interspaces, persisting on the body-whorl to the last quarter turn and running into a well-marked fasciole. Aperture narrow, channelled above, with a strong anterior sinus. Outer lip convex, reflexed. Columella with four primary and three secondary plaits, differing on paratypes. Inner lip spreading thinly over the ribs above, thick below.

Height, 70 mm.; diameter, 27 mm.

Locality.—Callaghan's, Stafford Town, Greymouth.

Holotype presented to the Collection of the New Zealand Geological Survey.

The number of ribs varies on different specimens. Holotype: 13 on the penultimate whorl, 16 on the body-whorl; paratype: 16 and 16. Resembles most *A. gatesi* Marwick, from which it differs in the larger size and heavier build, and also in the angle on the shoulder and the number of plaits on the columella. From *A. haweraensis* Marwick, it may be distinguished by the relatively higher spire, slightly less concave shoulder, different shape of the body, and the smaller aperture.

South Island Mosses Recently Found in the North Island.

By G. O. K. Sainsbury.

[*Issued separately, 30th September, 1931.*]

Owing to the industry of South Island collectors in the past, its moss flora has been decidedly better known than that of the North, with the result that a number of species are recorded as being confined to the former region. Of late, however, a good deal of field work has been done in several districts of the North Island, and this has led to the discovery of several southern species. Unfortunately, our knowledge of the distribution of the mosses in this country is so slight that the finder of a new station for a species has practically no data on which to decide whether he is confronted with a case of discontinuous distribution, more or less extreme, or whether there is a chain of intermediate stations linking up his find with the nearest known locality. Generally speaking, bryological collections are not made except by those specially interested in the group. The consequent paucity of field-workers and the outstanding difficulty of their task make it impossible for them to form any but provisional views on the distribution of even the most common species. So far as the rarer sorts are concerned, it suffices to mention that in the last few years, at least ten new or unreported species have been found in New Zealand, including representatives of genera, and even families, new to the country! In the subjoined list of South Island species found in the North Island, I have relied chiefly on Dixon's *Studies in the Bryology of New Zealand* for information as to the localities of the mosses in the south; whilst with regard to the North Island I have attempted, where the scanty knowledge at my disposal warrants it, to forecast what future research may show to be the comparative rarity of the species. A large or conspicuous plant is, of course, more easily established as "rare" than a small or insignificant one, and up to a point this is very true of the mosses, some of which are so handsome and striking as to catch the eye of a casual observer, whilst others are so insignificant as to escape the notice of an experienced bryologist. But it does not necessarily follow that because a moss is of striking appearance it will on that account be collected or noted by a student of the group. It may easily be passed over because of its superficial resemblance to some other species, and in this connection it must be remembered that very many mosses, even when in fruiting condition, cannot be identified without a microscopical examination. To put it bluntly, mosses often look very much alike, and the field-worker can never feel sure that he has noted or collected everything that even the most limited area has to offer. In order to facilitate the application of these considerations to the species in the list, I have given some particulars of size and appearance.

DICRANACEAE.

Dicranoloma grossialare (C. M.) Dixon.

SOUTH ISLAND.—Mt. Arthur Plateau, *T. F. Cheeseman.* NORTH ISLAND.—Mt. Hauhungatahi, National Park, *G.O.K.S.*

This is fairly distinct for a *Dicranoloma*, but the genus, though of striking habit, is so well represented and the plants so abundant in higher altitudes that this species may have been overlooked. Nevertheless, the careful collecting of Mr R. Mundy at Ohakune, quite close to Mt. Hauhungatahi, has apparently not brought it to light; neither has it been found by me on other parts of Mt. Ruapehu. I sought for it recently on Mt. Arthur itself without success, and expect that it will prove to be very rare.

Seligeria Cardotii R. Br. ter.

SOUTH ISLAND.—Fairly widely spread, according to R. Brown, but only on calcareous rock. I have found it on Mt. Arthur in a similar habitat. NORTH ISLAND.—Lake Waikaremoana, Hawke's Bay, alt. 2000ft; *G.O.K.S.*

On shaded limestone rock. A tiny plant, scarcely more than one-sixteenth of an inch high, including the seta. Such a minute species may well be comparatively common in its selected habitat, but no moss could more easily be overlooked.

Blindia tenuifolia (H.f. & W.) Mitt.

SOUTH ISLAND.—Waimakariri Glacier; *R. Brown.* STEWART ISLAND.—Mt. Thompson; *R. Brown.* NORTH ISLAND.—Mt. Ruapehu and Mt. Tongariro, National Park; *G.O.K.S.*

This is a montane moss that grows more or less submerged in glacial streams. In size and colour it is a striking plant, and the fact that it was only found twice by such an indefatigable collector as Brown, establishes it as a very rare species. I should think that the only possible extension of its northern distribution would be to Mt. Egmont.

Dicranella gracillima (C.M. & Beck.) Par.

SOUTH ISLAND.—Dunedin; Otarama; Broken River. NORTH ISLAND.—Lake Waikaremoana, *G.O.K.S.;* Ohakune, *R. Mundy;* Atiamuri, *K. W. Allison.*

This is a very small terrestrial moss, and easily overlooked. It is probably fairly common in this Island.

Dicranoweisia antarctica (C.M.) Par.

SOUTH ISLAND.—Widely spread on mountains. NORTH ISLAND.—Mt. Ruapehu (two localities); Rimutaka Hills, near Wellington, *G.O.K.S.*

Probably not uncommon in mountainous parts. In the field it strongly resembles robust forms of *Weisia viridula* (L.) Hedw., a very common moss, and could pass unnoticed accordingly.

Dicranum aucklandicum Dixon.

South Island.—Dunedin; Lake Te Anau; Kelly's Hill, West Coast Road. North Island.—Mt. Ruapehu, *G.O.K.S.* (two localities).

Another small terrestrial or rupestral species, and, of course, hard to find. It is impossible to form any opinion as to its distribution in this Island.

D. trichopodum Mitt.

South Island.—Otago, *Hector and Buchanan;* Paparoa Range, *R. Helms;* Clinton Valley, *D. Petrie;* Westland, *T. W. N. Beckett;* Mt. Arthur, *G.O.K.S.* North Island.—Ohakune, Mt. Ruapehu, *R. Mundy.*

In view of its fairly wide distribution in the South Island, I should expect it to be found here and there in the higher altitudes, but it is evidently rare. A fairly robust and quite noticeable moss, at any rate in fruit.

Mesotus celatus Mitt.

South Island.—Otago, *Hector and Buchanan;* Marlborough, *J. H. McMahon;* Mt. Arthur, *G.O.K.S.* North Island.—Mt. Hikurangi, 4500ft., *G.O.K.S.*

This moss, though a very rare fruiter, is conspicuous and distinct. It is remarkable that it has not been found on the central mountains of the North Island, and that Mt. Hikurangi, East Cape district, should be the only station for it at present.

Fissidentaceae.

Fissidens inclinabilis C.M.

South Island.—Christchurch and Dunedin. North Island.—Wairoa County, Hawke's Bay, *E. A. Hodgson, G.O.K.S.;* Atiamuri, *K. W. Allison.*

Like several of the New Zealand species of the genus, this is a very small terrestrial plant, and is probably not so rare as easily overlooked.

Pottiaceae.

Didymodon Binsii (R. Br. ter.) Dixon.

South Island.—Port Lyttelton Hills, *R. Brown.* North Island.—Wairoa County, Hawke's Bay, *E. A. Hodgson; G.O.K.S.*

This is a small ground moss that grows in open places and is fairly conspicuous. It is not uncommon in the Wairoa district, but has apparently not been collected elsewhere, and is probably rare.

Tortula bealeyensis R. Br. ter.

South Island.—Fairly widely distributed. North Island.—Lake Waikaremoana, 2000ft., *G.O.K.S.;* Ohakune, 2000ft., *R. Mundy.*

This is a fine species, and is not likely to be overlooked by a collector, though it could be confused in the field with other robust members of the genus. An extension of its distribution in mountainous districts can reasonably be expected.

FUNARIACEAE.

Physcomitridium Readeri (C.M.) Roth.

SOUTH ISLAND.—Banks of River Avon, *R. Brown.* NORTH ISLAND.—Wairoa County, in drain, *E. A. Hodgson.*

An interesting little cleistocarpous moss which must be very rare.

LEPYRODONTACEAE.

Lepyrodon Lagurus (Hook) Mitt.

SOUTH ISLAND.—Probably fairly widely distributed. NORTH ISLAND.—Mt. Ruapehu, *R. Mundy; G.O.K.S.*

A specimen in Colenso's Herbarium from an unlocalised finding is probably of his own collecting in Hawke's Bay district.

L. australis Hampe.

SOUTH ISLAND.—Several stations. NORTH ISLAND.—Lake Waikaremoana, *E. A. Sainsbury;* Mt. Ruapehu, *G.O.K.S.*

Both the above species are well-marked corticolous plants, and are probably fairly well distributed in mountainous parts.

ENTODONTACEAE.

Entodon truncorum Mitt.

SOUTH ISLAND.—Canterbury and Otago. NORTH ISLAND.—Lake Waikaremoana, *G.O.K.S., E. A. Hodgson.*

This is quite a conspicuous moss, but as it resembles *Plagiothecium denticulatum* in the field, it may have been passed over as that.

Pseudoleskea imbricata (H.f. & W.) Broth.

SOUTH ISLAND.—Rare. NORTH ISLAND.—Mahia Peninsula, Hawke's Bay, on limestone rocks by sea; *G.O.K.S.*

Quite distinct in its terete branches and the close imbrication of the leaves when dry. I found it growing sparingly with *Grimmia pulvinata,* var., *Barbula torquata,* etc., on limestone boulders at the very edge of the sea, but not more than a few yards inland. Perhaps it will be found in other parts of the coast in a similar habitat. It could not be mistaken for any rupestral moss.

AMBLYSTEGIACEAE.

Sciaromium Bellii Broth.

SOUTH ISLAND.—Otago, Southland, and Marlborough. NORTH ISLAND.—Patoka, Hawke's Bay, *E. A. Hodgson.*

This is a very rare water moss. The Patoka plant is also outstanding in that it is the only gathering in fruiting condition, there being a capsule present.

A Note on the Life History of Diplodon lutulentus Gould.

By E. Percival, B.Sc., Professor of Biology, Canterbury College, Christchurch.

[*Received by Editor, 7th August, 1930; issued separately, 30th September, 1931.*]

The *Unionidae* are well known on account of the modification of their development, which includes a parasitic stage where the larva (Glochidium) attaches itself to various parts of fishes and becomes enclosed by the upgrowth of skin. During the period of enclosure a metamorphosis takes place, the rudiments of adult organs, already present, becoming further developed, until finally, with the complete appearance of definite adult structures, the young organism is liberated and proceeds to follow the normal benthic life of the adult.

Lillie (4) has carefully followed the embryonic development of *Unio*, and has shown that the development of the embryo agrees largely with the process occurring in *Dreissensia.* There are modifications, such as the absence of a prototroch and the retardation of the differentiation of the rudiments of the gut, nervous system, and pedal musculature. *Harms* (2) has examined closely the post-embryonic development, following the growth of the chief organs during the parasitic life. Among the striking peculiarities of the early life of the Unionid larva is the modification in the mode of feeding. The larval mantle possesses a large mass of vacuolated cells on each flap, which absorb food material derived from the host. *Curtis* and *Lefevre* (1), in a paper full of information, have examined the larvae of a large number of North American species, carrying out experimental infections in order to determine any specificity in the parasitism and any effects on the host. They have described and figured hooked and hookless larvae and point out that the byssal thread, characteristic of the larvae of *Anodonta* and *Unio*, is absent, in their experience, from a number of genera of hookless larvae (*Lampsilis, Obliquaria, Obovaria, Plagiola, Pleurobema, Quadrula, Tritogonia*) and from the hooked larvae of *Symphynota* (*l. c.*, p. 94). *Simpson* (5) has subdivided the *Unionidae* into two chief groups based on the use made of the various gills as brood pouches or marsupia. Those in which the eggs are carried in the outer or all four gills are described as exobranchiate, and include European and North American species, while those carrying the eggs only in the inner gills are endobranchiate. The latter group contains species found in Central and South America, Africa, Asia, and Australasia. *Diplodon* is an endobranchiate mollusc.

The larva of Diplodon lutulentus.

The figures of the Glochidia given by Curtis and Lefevre (*l. c.*, p. 97) show that the organisms seen from the side, bear shells which approximate in form to an isosceles triangle or some modification thereof. In those cases in which there is not a pointed apex, the ventral edge is symmetrically rounded so that the middle of the curve lies directly below the middle of the hinge. The Glochidium of

Diplodon, on the other hand, has a shell which is asymmetrical when seen from the side (fig. 1). The apex of the valve is anteriorly placed so that, with the hinge as base-line, the angle made by it and a line from the anterior end to the apex of the valve is about 80° while the posterior angle is about 55°. The dimensions are length 0·36 mm., depth from hinge to hook 0·28 mm.

There is a well-marked calcareous shell, densely pitted, and very pale brown in colour. The hooks carry each a tooth at the tip but no more. They make a wide angle with the plane of the valve (fig. 2), thus presenting an arrangement for the easy transfixing of any suitable tissue with which they come into contact. The adductor muscle is placed towards the anterior border (fig. 3). As is usual, the greater portion of the animal consists of larval tissue with strongly staining nuclei (Delafields Haematoxylin and Acetic Alum Carmine) and feebly staining cytoplasm. There have been seen no signs of sensory cells or so-called "byssal thread," either in living or in stained material, such as are shown in the Glochidium figured by Lillie (*l.c.*). The rudiments of the adult organisms stain very clearly, showing up as four chief masses (fig. 3), the oral plate lying anteriorly and ventrally to the muscle, a large patch of cells lying transversely behind and showing three regions, two lateral patches each including a vesicle, no doubt homologous with the "lateral pit," and a median portion which probably represents the foot rudiment. I have seen no sign that "lateral pits" exist as such, there being ample indication that the spaces are completely enclosed and cut off from the mantle cavity. Behind each lateral vesicle is a patch of cells which may be double (fig. 3), and probably represents the kidney rudiment.

Infection in Nature.

The Glochidia are ripe from the end of November to the end of January. The adults have been found to frequent the stony beds of several small lakes in West Canterbury, notably Lake Sarah, by the Midland Railway line, at an altitude of about 1800ft. Collections made at the end of November with a tow-net trailed slowly about six inches from the bottom, contained a large number of Glochidia. It is difficult to say whether the larvae were actually floating or were ejected by the parents as a result of the disturbance caused by the passage of the net through the water. It is probable that the latter is the explanation since, in such quiet water, organisms such as they with their relatively heavy shells would fairly readily sink after being ejected. Curtis and Lefevre (*l.c.*, p. 98) have referred to the inability of Glochidia to propel themselves in spite of their flapping valves. They also (p. 101) point out that hooked Glochidia respond actively to tactile stimuli by closing up immediately on being touched. This applies equally well to the larvae of *Diplodon*.

Natural infections have been found in the young forms of the fishes, *Galaxias brevipennis* Günth. and *Gobiomorphus gobioides* Cuv. & Val. In the former case, the hosts were about 4·5 cm. long, and carried the parasites on the pectoral fins. In the latter case, the fish were about 1 cm. in length. The Glochidia had taken hold in various places, on the pectoral fins, on the upper lip clasping the

maxillary region, on the roof of the mouth, on the snout, in fact any place appeared suitable for attachment. A number of young *Gobiomorphus* was taken in Lake Mason, North Canterbury, at the edge of the water, and most of the specimens were infected. It is the habit of the small post-larval *Gobiomorphus* rather to keep at the bottom seeking food among the stones and vegetation, so that the heavy infections which were found, as many as six on the head and pectoral fins of an animal less than 1 cm. in length, is not to be wondered at. The post-larval *Galaxias* also tend to keep near the edge of the lake or stream, this depending on many conditions, one being the rate of flow which may drive them down or near to the edge. In lakes they are more often found, at the stage of 4 or 5 cm., swimming near the surface feeding on free floating particles rather than upon the more benthic material. The relatively light infections, three Glochidia at most, found on the young *Galaxias*, may be accounted for largely by the consideration of this habit of feeding nearer the surface.

Metamorphosis.

Little can be said about the metamorphosis in *Diplodon* save that it follows the lines of that of *Anodonta*, etc. The material, incidentally collected with the hosts, consisted chiefly of newly-fixed Glochidia, especially in the case of the small *Gobiomorphus*, while the more advanced stages were found in the specimens of *Galaxias*. Figure 4 shows the condition of the most advanced specimen. The oral plate has given rise to the stomodæal invagination which at present has not opened into the enteric sac. The digestive diverticula have already appeared on the sides of enteron, but there is as yet no trace of a proctodaeum. The foot is indicated, but in sections of a similar stage the nervous system could not be identified.

The Early Growth of the Shell.

Latter (3 pp. 193-195) has pointed out that the hooks of a mussel newly set free exert pressure on the ventral edge of the growing shell, thus causing a notch. He gives figures of the shell of *Unio* (fig. 37 *l. c.*) showing slight dorsal curves of the growth-lines brought about by the notch. In *Diplodon* such curves are not seen, and in *Anodonta cygnea*, during the early period of free life up to the time when the shell is at least 2·5 cm. long, it is possible to infer what has taken place. Fig. 5 shows the umbones of a small specimen of *A. cygnea* which carries the undamaged glochidial shell *in situ*. The hooks, supported by the inturned horny edge of the shell during early growth, undoubtedly come in the way of the growing adult shell which, owing to the indentation of the mantle through the same cause, carries permanently a depression in each valve into which the glochidial hook projects. With further radial extension of the mantle the outline becomes uniform, very soon ceasing to show signs of the effects of the hooks. After recovery, the growth of the mantle and shell proceeds uninterruptedly for a short time and a normal unaffected growth-line is formed (see fig. 5). However, when the next growth-line is about to be formed, a longi-

tudinal ridge appears in the same radius of the shell as that in which lies the hook. This is repeated several times until four or five ridges are produced lying parallel to each other and increasing in length in passing from the umbo. After the careful examination of some dozen young shells, of which fig. 5 is an example, the conclusion arises that the mantle recovers from the effects of being caught up by the glochidial hooks, at any rate in *Anodonta cygnea*, and the ridges and other irregularities which are produced later in the same sector of the shell are due to other causes.

POSTSCRIPT.—Since the above was written, a small specimen of *Diplodon lutulentus*, 5 mm. long, has come into my possession. This shows unmodified adult shell growth for 1 mm. from the glochidial shell after which two series of ridges are formed, one series arranged in an antero-ventral direction, the other two in a postero-ventral line. There is also here no indication whatever that adult shell formation has been modified by the parts of the glochidial shell.

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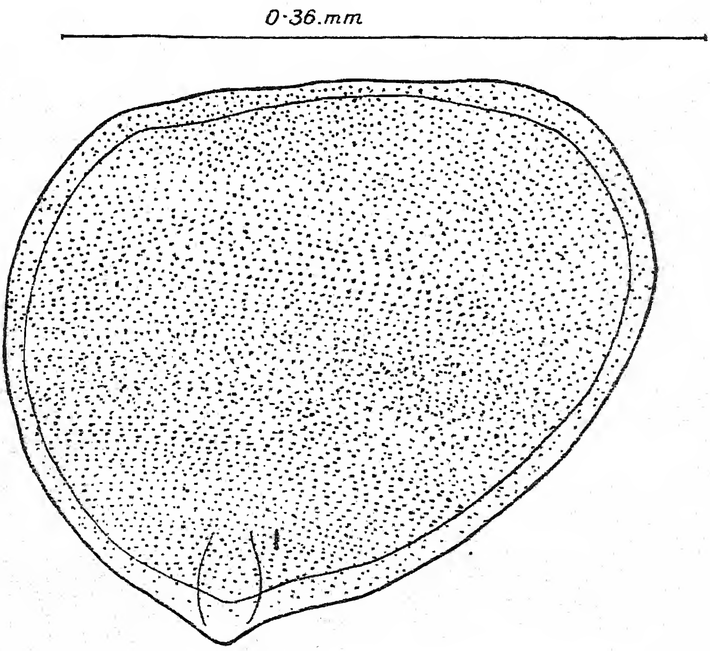

Fig 7

External view of Glochidium of *Diplodon lutulentus*.

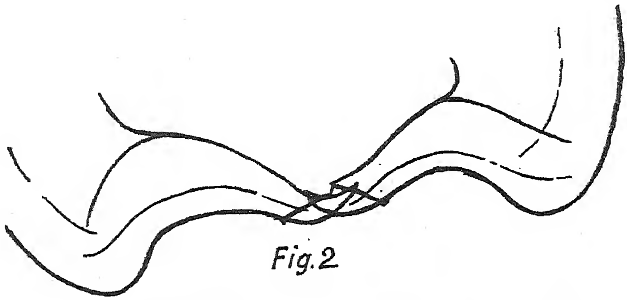

Fig. 2

Hooks of Glochidium seen along antero-posterior axis.

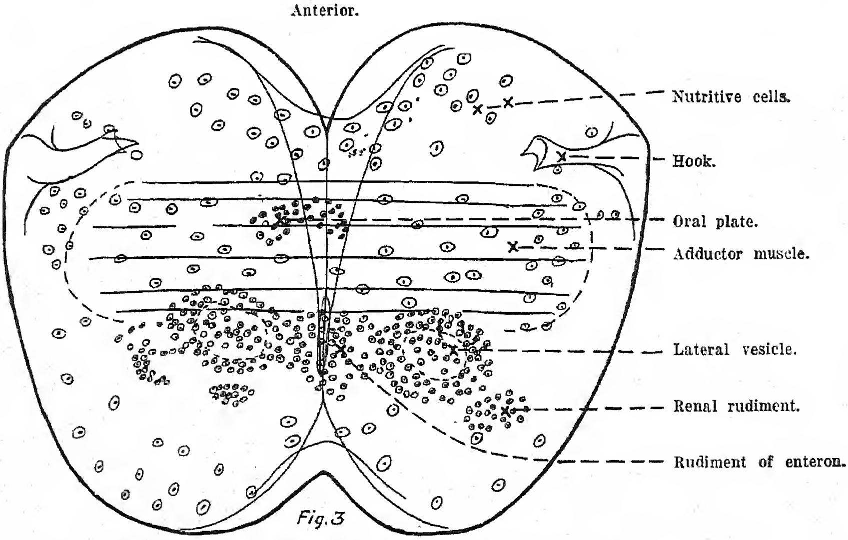

Fig. 3

Glochidium of *Diplodon lutulentus* from inside.

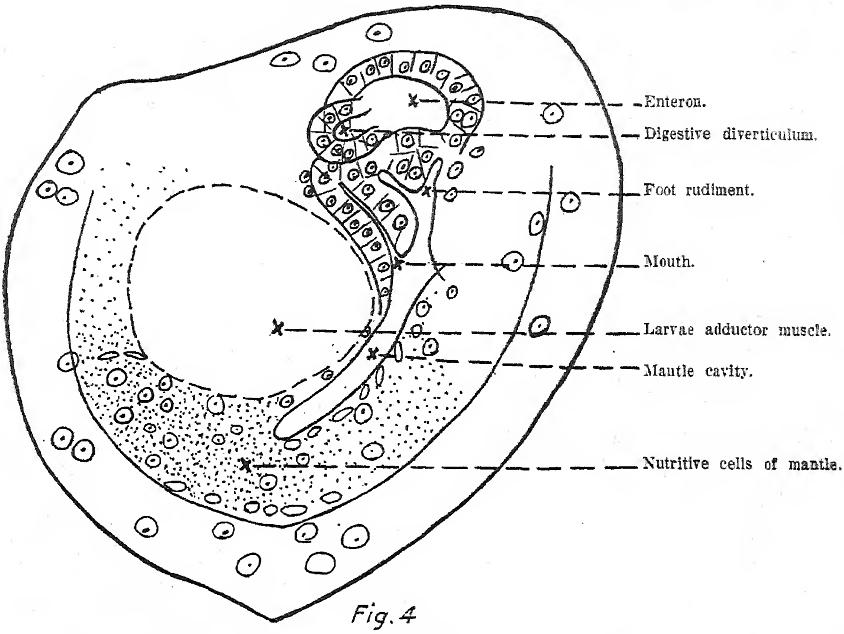

Fig. 4

Stage in metamorphosis of *Diplodon lutulentus* taken from *Galaxias brevipennis*.

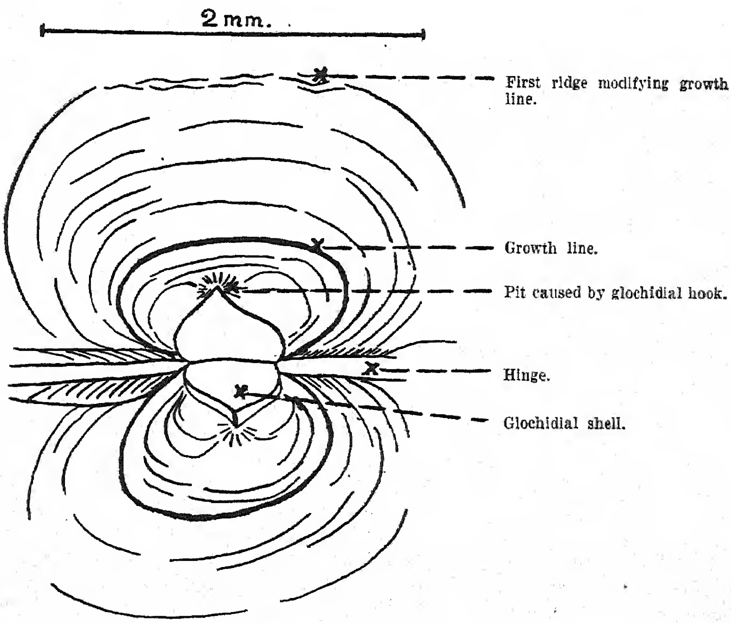

Fig. 5

Umbo of shell of *Anodonta cygnea* showing relations between glochidial shell and adult shell.

New Species of New Zealand Lepidoptera.

By Edward Meyrick, B.A., F.R.S.

[*Issued separately; 30th September, 1931.*]

(For the material for the following descriptions I am again indebted to the kindness of my friend, Mr G. V. Hudson.

Caradrinidae.

Melanchra tetrachroa n. sp.

♀ 37 mm. Head dark grey, mixed light greenish. Palpi, pale greyish-ochreous, with three blackish bars, projecting scales of second joint grey. Thorax, dark grey mixed black, crests and tegulae except margins moss-green. Forewings rather elongate-triangular, termen rather obliquely curved, crenate; ashy-grey, ground colour largely obscured by moss-green and black markings; a green subcostal streak from base to $\frac{5}{8}$ with several black transverse marks, costal edge above this posteriorly blackish with three whitish dots; basal third green except on veins, with two oblique black streaks beneath cell near base, beyond these a small spot of pale brownish edged posteriorly by a blackish mark, just above dorsum a strong black longitudinal streak edged white beneath; dorsal edge pale ochreous-brown throughout, marginal scales whitish; first line curved, green, edged black posteriorly, interrupted on veins; oblique-oval orbicular and curved-transverse reniform green, very finely whitish-edged, united by a trapezoidal deep black blotch, and externally black-edged with adjacent spaces mixed green and black; claviform represented by a rounded black blotch mixed green resting on first line; second line green and whitish, edged black anteriorly, interrupted on veins, angulated above and bidentate below middle, followed by a green fascia interrupted on veins; subterminal line forming three nearly straight segments united by light ochreous-brown spots, two lower white strongly edged black suffusion, upper represented by thick blackish anterior margin and a pale green blotch extending to apex; a terminal series of black crescentic marks preceded by green spots; cilia pale greenish. Hindwings grey; an interrupted dark grey terminal line; cilia, grey whitish, a grey subbasal line round upper part of termen.

Waimarino National Park, 2800ft., January, at sugar (*G. V. Hudson*) ; one specimen. A beautiful insect of complex ornamentation.

Melanchra pelanodes n. sp.

♂ 36 mm. Head, thorax pale moss-green mixed whitish and sprinkled black, a black transverse bar on collar, thoracic crests suffused deep red-brown. Palpi dark grey, mixed deep reddish. Antennae bipectinated to $\frac{3}{4}$ (about 2). Forewings somewhat elongate-triangular, termen rather obliquely curved, hardly waved; grey irrorated white and black and irregularly mixed dull green, edges of markings partially roughened; dorsal edge mixed red-brown; sub-

basal line partially edged black, a green spot following this beneath cell; first line nearly straight, partially edged black; orbicular subquadrate, laterally edged white and then black, reniform subquadrate, formed by a green bar between two black ones followed by a white blotch edged black posteriorly, beyond this a reddish-brown space, space between them tinged reddish-brown, claviform represented by a rounded reddish-grey spot edged posteriorly white and then black, four white dots on costa beyond middle surrounded black; second line formed by a contorted grey streak irrorated white, edged anteriorly by some blackish scales; subterminal slender, whitish, shortly angled towards costa and shortly bidentate beneath middle, in disc edged anteriorly green suffusion mixed black towards middle, on dorsal third suffused pale rosy-brown and preceded by a subcrescentic dark fuscous blotch, posteriorly edged blackish suffusion except towards extremities, on costa edged black anteriorly: cilia light brownish, slenderly barred whitish, a dark grey antemedian and red-brown apical line. Hindwings grey; cilia grey, base and tips whitish.

Waimarino National Park, 2800ft., January, at sugar (*G. V. Hudson*); one example, taken on the same night as the preceding. These two species are undoubtedly allied together, but the differences are such that it is not credible that they can be only sexes of the same. Both examples are in very fine condition.

Melanchra scutata Meyr.

Mr Hudson sends what is probably the ♀ of this; forewings ground-colour light grey except in middle of disc, orbicular roundish, reniform posterior ⅔ white, subterminal line more suffused white; although differing thus considerably in appearance from the two ♂ specimens which I have seen, I think it is the same species.

Melanchra coctilis n. sp.

♂ 39 mm. Head, palpi, thorax red-brown, partially sprinkled ochreous-whitish. Forewings rather elongate-triangular, termen crenulate; red-brown, along costa sprinkled ochreous-whitish; subbasal line in disc shortly whitish edged black; first and second lines hardly paler than ground colour, waved; spots very finely edged black, orbicular oval, slightly touched white within margin, open above, claviform hemispherical, resting on first line, reniform mostly finely edged white within black margin except beneath; subterminal line consisting of small fine disconnected white filaments placed in small suffused dark fuscous spots: cilia red-brown, two darker shades. Hindwings rather dark grey; cilia light red-brown.

Flora River, bred January from larvae feeding on *Nothofagus Menziesii*, two examples (*G. V. Hudson*). Larva moderately stout, very dark rich green finely speckled with yellow dots and still more finely with blackish, especially on ventral surface; a very conspicuous wavy serrate white lateral line faintly edged with orange-pink above near middle of each segment: of very sluggish habit, resting amongst foliage in form of a loop; in this position the wavy serrate lateral line gives exactly the effect of the slightly serrate edge of the leaf of *N. Menziesii*, and a detection of the larva in situ is almost impossible: absolutely distinct from the larva of *M. ochthistis*.

Hydriomenidae.

Chloroclystis tornospila n. sp.

♂ 25 mm. Head whitish marked green. Palpi light green speckled blackish. Antennae with slender fasciculate-ciliated filaments (4). Thorax light green mixed black and whitish. Abdomen with blackish subbasal ring. Forewings somewhat elongate-triangular, termen bowed, oblique; green; first five fasciae indicated by two or three waved curved striae each of whitish speckling, alternating with blackish striae on costal half, which are indicated on dorsal half only by black marks on veins, sixth obsolete; subterminal line waved, of whitish speckling, preceded near tornus by a small well-marked black spot; a blackish terminal line: cilia basal half light green barred blackish-grey, outer half paler. Hindwings termen somewhat unevenly rounded; light grey, tinged green towards termen, dorsal area greener striated white and blackish; a grey discal dot and waved subterminal line; a blackish terminal line; cilia grey, basal half light greenish spotted blackish.

Waimarino National Park, 2800ft., January (*G. V. Hudson*). Nearest *muscosata*.

Asaphodes amblyterma n. sp.

♂ 24 mm. Head, palpi thorax grey irrorated whitish. Antennal pectinations 6. Forewings triangular, apex somewhat prominent-rounded, termen little oblique, somewhat sinuate above, rounded beneath; grey; costal edge ochreous-whitish spotted dark grey; median band broad, with faint ochreous tinge, preceded by a slightly curved fascia of 3 or 4 dark fuscous striae separated by light grey, and limited posteriorly by 3 dark fuscous striae separated by whitish lines becoming white in disc above middle, rather prominent-curved in middle, beyond these a thick dark fuscous shade on costal half of wing: cilia grey, outer half whitish in sinuation. Hindwings light grey; a faint darker curved postmedian line; cilia light grey, outer half whitish-tinged.

Whangarei, December (*Commander Patterson*); one example.

Phycitidae.

Homoeosoma ischnomorpha n. sp.

♂ 27 mm. Head, palpi, thorax grey speckled whitish. Forewings narrow, gradually dilated, termen slightly rounded, rather oblique; 5 absent; grey speckled white and irregularly sprinkled black; an indistinct dark fuscous mark on costa about ⅓, and traces of rather oblique first line; two indistinct dark fuscous dots on angles of cell; some brownish suffusion towards apex, and a marginal series of small cloudy dark fuscous spots round apical part of costa and termen: cilia grey speckled whitish. Hindwings whitish-grey; cilia whitish.

Whangarei, December (*Commander Patterson*); one example.

Salebria oculiferella Meyr.

Whangarei, March (*Commander Patterson*); one example. Mr Hudson states that a specimen was also taken by Mr C. E. Clarke at Lake Rotomahana in February, 1915, but apparently not recorded. The species is a native of Eastern Australia, where it is not uncommon; in New Zealand doubtless an immigrant.

PYRAUSTIDAE.

Scoparia ustiramis n. sp.

♂ 16 mm. Head, thorax grey mixed white. Palpi dark grey, apical edge white. Forewings elongate-triangular, termen slightly rounded, oblique; grey, costal and dorsal thirds suffusedly irrorated white; an irregular streak of black irroration beneath cell from base to end; a slenderer black streak in cell from middle to end, terminating in a white dot on angle of cell, and five rather irregular black lines on veins to termen, black dots on ends of terminal veins: cilia whitish-grey, a light grey subbasal line. Hindwings light grey; cilia pale grey, a darker subbasal shade.

Whangarei, January (*Commander Patterson*); one example. Allied to *subita* Philp.

TORTRICIDAE.

Capua alopecana Meyr.

I have recently received from Mr Hudson specimens of this insect, bred from larvae on *Phyllocladus alpinus*, taken at Waimarino in January. As the result of further examination, I find that veins 7 and 8 in forewings are distinctly stalked, the stalk in some specimens being very short. The species, which was formerly placed in *Tortrix*, should now be referred to *Capua* as above.

OECOPHORIDAE.

Borkhausenia comosaris n. sp.

♂ 13 mm. Head grey. Palpi dark grey sprinkled whitish. Thorax grey, tegulae yellowish except shoulder. Forewings elongate, costa gently arched, apex obtuse, termen obliquely rounded; ochreous-yellowish, slightly orange-tinged; a rather thick dark grey costal streak from base to near $\frac{2}{3}$, apex pointed; plical stigma forming a small group of blackish scales; some slight fuscous sprinkling from lower angle of cell to tornus: cilia ochreous-yellowish. Hindwings grey; an expanded group of erect grey hairs occupying base of wing; cilia light grey.

Wellington, December (*G. V. Hudson*); one example. Peculiarly distinguished by the expanded hairs of hindwings, doubtless a sexual character.

Trachypepla polyleuca n. sp.

♂ ♀ 15-16 mm. Head white sprinkled grey. Palpi dark fuscous, base and apex of terminal joint white. Thorax white, anterior margin dark fuscous. Forewings elongate, costa gently arched, apex obtuse-pointed, termen very obliquely rounded; white; an elongate dark

fuscous spot on base of costa; an irregular dark grey black-edged transverse fascia before middle, constricted beneath costa, dilated in disc, including a large subdorsal tuft; an elongate-semioval blackish blotch on costa beyond middle, from which an irregular transverse streak of grey and black scales runs to dorsum; an irregular transverse series of grey and black scales in disc beyond this; an irregular dark fuscous apical blotch: cilia grey. Hindwings and cilia grey.

Whangarei, December (*Commander Patterson*); two examples. Nearest *conspicuella*, but quite distinct.

Izatha mesoschista n. sp.

♂ ♀ 18-22 mm. Head white sometimes sprinkled grey. Palpi white, second joint dark fuscous except apex; terminal joint with dark fuscous median band. Forewings elongate-oblong, apex obtuse, termen rather oblique; white irrorated light fuscous; narrow elongate fuscous spots on costa at base and before and beyond middle; a fine black plical line from base to $\frac{1}{3}$; a slightly downcurved longitudinal black streak in disc from about $\frac{1}{3}$ to $\frac{2}{3}$, edged brown suffusion beneath; a cloudy fuscous subcostal streak from middle to $\frac{3}{4}$; some dark fuscous or blackish dots round apical part of costa and termen: cilia grey-whitish. Hindwings pale grey; cilia grey-whitish.

Wellington, December, January (*G. V. Hudson*); seven examples. Mr Hudson has pointed out to me that this has been confused with *balanophora*, from which it is easily separable by the strong black streak in middle of disc. Owing to this confusion, for which I am primarily responsible, Mr Philpott has described the true *balanophora* Meyr., under the name of *Milligani* (Trans. N.Z. Inst. LVIII, 87).

CARPOSINIDAE.

Paramorpha heptacentra n. sp.

♂ 12 mm. Head, thorax whitish. Palpi dark fuscous, apical edge whitish. Forewings elongate, slightly dilated, costa gently arched, apex obtuse-pointed, termen nearly straight, oblique; whitish costal edge tinged yellowish; some scattered black specks except towards costa; a black slightly raised dot beneath fold at $\frac{1}{5}$, two towards costa at $\frac{1}{3}$ and before middle, one in disc between these, two at angles of cell, and one at dorsal end of fold in a slightly oblique line with these; one or two blackish dots on tornal edge: cilia whitish. Hindwings and cilia whitish.

Whangarei, January (*Commander Patterson*); one example. Allied to the Australian *aquilana* Meyr.; there are several other Australian species of *Paramorpha*, but the genus is new to New Zealand.

TINEIDAE.

Sagephora subcarinata n. sp.

♂ 11 mm. Head grey, face white. Palpi blackish, terminal joint and apex of second white. Antennae white ringed dark grey, a broad dark grey band towards apex. Thorax whitish streaked

dark fuscous. Forewings elongate, costa gently arched, apex obtuse, termen obliquely rounded; fuscous irrorated darker; a blackish costal patch from base to $\frac{3}{4}$, narrow at base, posterior edge rather inwards-oblique from costa and reaching half across wing, lower edge margined white except on a short median flange, a blackish discal dot just beyond its angle: cilia light grey, a somewhat interrupted blackish subbasal line. Hindwings and cilia grey.

Gollans Valley, Wellington, January (*G. V. Hudson*): one example.

Tinea texta n. sp.

♀ 7 mm. Head whitish centrally mixed fuscous. Palpi fuscous tip white. Thorax whitish mixed dark fuscous. Forewings light fuscous; first half of wing occupied by three obscure whitish angulated fasciae irregularly edged dark fuscous, third broadest and angle reaching beyond middle of disc; an oblique white strigula from costa about $\frac{3}{5}$, and three small white spots between this and apex, wing beneath these irregularly irrorated whitish, some dark fuscous scales, a fine white erect strigula from middle of termen; a small suffused black apical spot: cilia greyish, two dark fuscous lines. Hindwings and cilia light grey.

Whangarei, January (*Commander Patterson*); one example.

ADDENDUM.

XYLORYCTIDAE.

Donacostola n. g.

Head with appressed scales, sidetufts loosely raised; ocelli posterior; tongue developed. Antennae $\frac{3}{4}$, ♂ dentate, shortly ciliated ($\frac{1}{2}$), scape rather long and stout, without pecten. Labial palpi very long, curved, ascending, second joint much exceeding base of antennae, with appressed scales, terminal joint shorter than second, slender, acute. Maxillary palpi rudimentary. Posterior tibiae with scales somewhat rough above. Forewings 1b furcate, 2 from near angle, curved, 7 and 8 stalked, 7 to termen, 11 from middle. Hindwings considerably over 1, trapezoidal-ovate, termen not sinuate, cilia $\frac{1}{4}$-$\frac{1}{3}$; 2 from $\frac{3}{5}$, 3 and 4 connate, 5 parallel to 4, 5-7 rather approximated towards base.

Type *notabilis* Philp. Mr Philpott has provisionally referred this species* (of which I have received a pair by the kindness of Mr Hudson) to the genus *Euprionocera* Turner, which I have not seen, but Dr Turner has regarded his genus as an Oecophorid. The present species is not Oecophorid by reason of the hindwings; I refer it to the group of *Odites* in the *Xyloryctidae,* of which it is perhaps an early form. Its place in the New Zealand fauna is between *Scieropepla* and *Agriophara.*

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*Trans. N.Z. Inst., LVIII., 368.

A Fossil Nothofagus (Nothofagoxylon ?) from the Central Otago Coal-Measures.

By W. P. Evans, M.A., Ph.D.

[*Read before the Wellington Philosophical Society, Geological Section, 8th October, 1930; received by Editor, 18th October, 1930; issued separately, 30th September, 1931.*]

The broken carbonised stem referred to in this paper was taken directly from a face in the open workings at Coal Creek Flat, some four miles north of Roxburgh, Central Otago.

After a short treatment with hydrofluoric acid and prolonged boiling in water portions of the wood cut fairly well, and showed sufficient detail to allow it to be identified as that of a New Zealand beech.

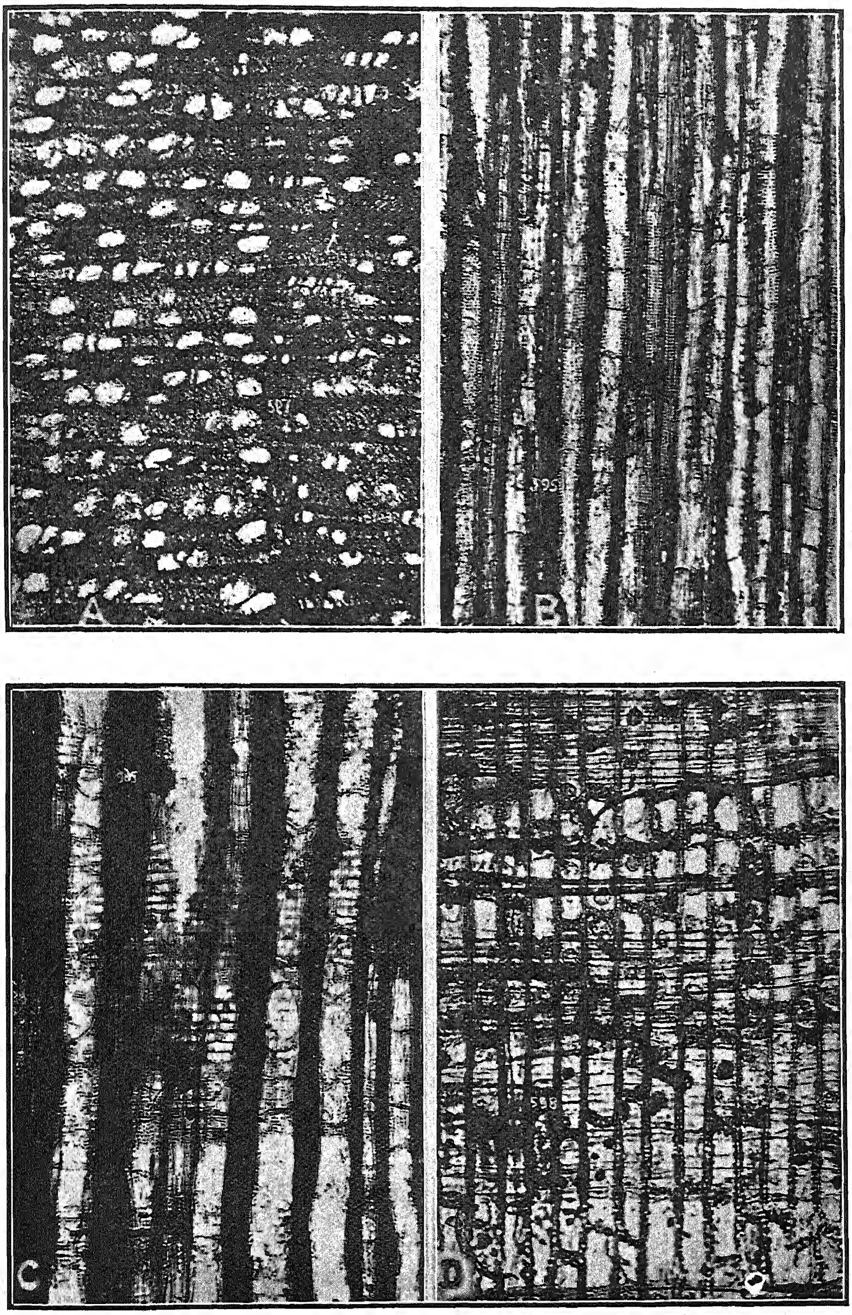
The accompanying photomicrographs of transverse, radial, and tangential sections show so clearly the structure of the wood that detailed description is unnecessary.

The coal from which the wood was taken has evidently been derived chiefly from wood, which, in some sections at any rate, is all drift material. Short stumps and roots lie at all angles in the coal, and generally some fine prostrate trunks are visible. To the unaided eye nearly all the wood appears to be of one sort, but microscopical examination proves that both angiosperms and conifers are represented.

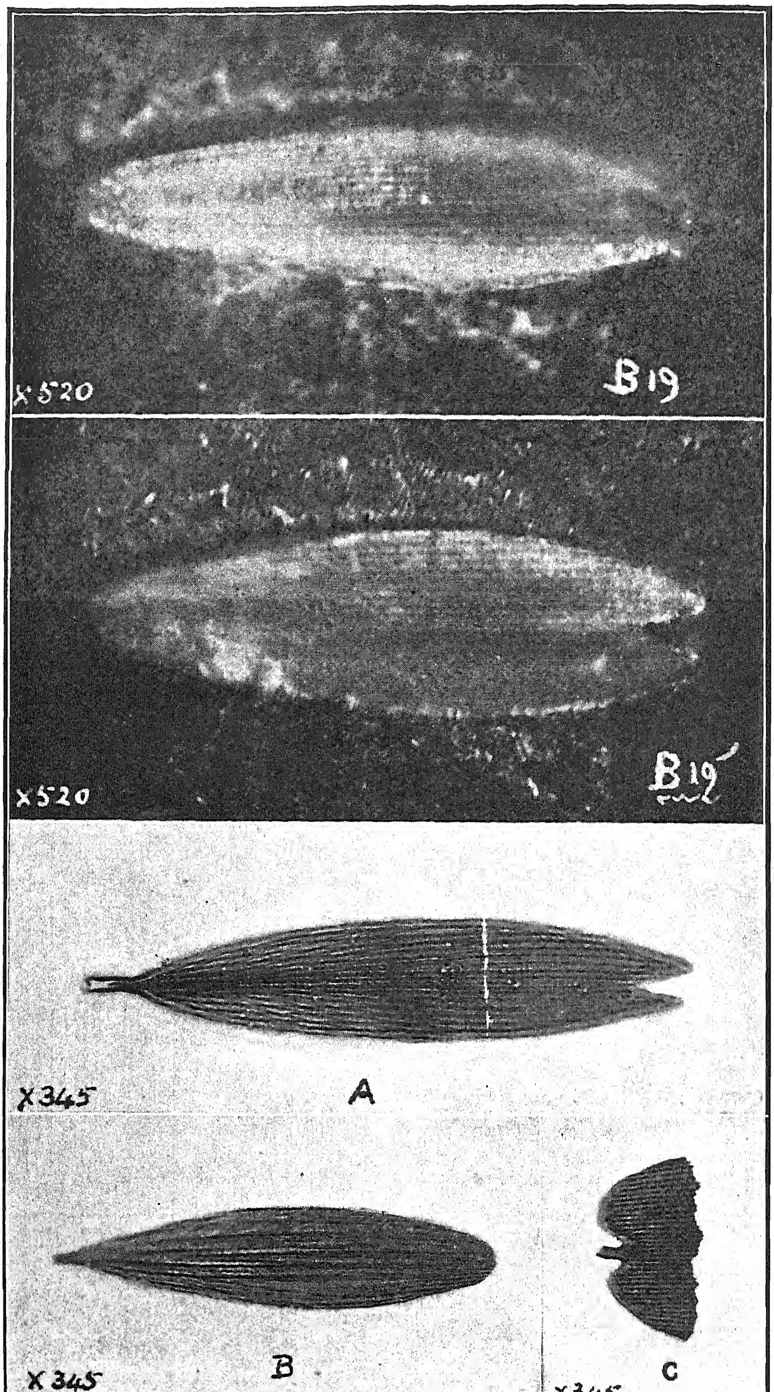
The exact geological age of the measures at Coal Creek Flat is still uncertain. Professor R. Speight, in whose company the writer has been lucky enough to make more than one visit to the district, has not yet found any fossils other than the wood, so that this very important line of evidence as to age is missing. We have therefore to trust to comparisons with similar areas in other parts of Central Otago, *assuming* that they were laid down at the same time. The St. Bathans beds have been recently placed by Henderson* in the lower Pleiocene, and, as the beds at Coal Creek Flat are comparable with the St. Bathans beds, it seems likely that they also may be regarded as of Pleiocene age.

The occurrence of fossil beech-wood showing a structure almost identical with that of our present *Nothofagus fusca* proves clearly that the beeches have flourished in New Zealand for a considerable time.

*Henderson, J.; *Trans. N.Z. Inst.*, vol. 60, 1929, p. 294a.



Sections of fossil *Nothofagus* from Coal Creek Flat; A., transverse, × 55; B., tangential, × 55; C., radial, × 55; D., radial, × 170.



Scale from Glen Afton coal, and recent wing-scales. Explanation in text.

Traces of a Lepidopterous Insect from the Middle Waikato Coal-Measures.

By W. P. EVANS, M.A., Ph.D.

[*Read before the Wellington Philosophical Society, Geological Section, 8th October, 1930; received by Editor, 18th October, 1930; issued separately, 30th September, 1931.*]

IN February of this year, Professor J. A. Bartrum, of Auckland University College, was good enough to forward to me for examination some small pieces of coal from the Glen Afton mine, near Huntly, which appeared to show a somewhat abnormal structure. The coal was finely laminated and, on the faces of most of the laminae, were one or more small, almost circular, and definitely fringed impressions, many of which had an irregular, highly coloured central spot. The coal had been sent to Professor Bartrum by one of his former students, Mr F. L. Swan, and later (May, 1930) a further similar specimen was forwarded by Mr A. F. Papesch.

In order to determine whether the fringed bodies had any appreciable thickness, small slices of the coal were ground for examination under the vertical illuminator, and during the preliminary examination of one or two of these slices the writer's attention was drawn to some very small pinkish striated fragments which, owing to their high reflecting power, stood out very clearly from the generally dull surface of the coal.

In one slice, ground (by sheer good luck) to just the right plane, an almost unbroken and well striated example of the pinkish bodies was found and, on closer examination, appeared to be an insect scale.

The accompanying photomicrographs, B19 and B19[1] in plate (X 520) show the scale as it lies in the coal surface. The photographs were taken with the iris diaphragm of the vertical illuminator almost closed, and, in consequence, the surrounding coal, which lies at a slightly lower level (owing partly to the grinding process and partly to the slight upward curvature of the scale), is only dimly shown.

Dr R. J. Tillyard, Chief of the Division of Economic Entomology of the Commonwealth of Australia, to whom the photographs were sent for criticism, was kind enough to supply the following comments: "Although there are several points that are puzzling in your photomicrographs, yet I think I am prepared to state that they represent an insect scale. An examination of the longitudinal and cross-striation shows that it probably belongs to the Lepidoptera. Scales occur in other orders of Insects, notably in the Collembola, the Thysanura, the Copeognatha, the Coleoptera, the Diptera, and the Trichoptera. The type of striation in all of these is markedly different from that of the higher Lepidoptera, which alone, of all these, have the longitudinal striations divisible into two groups, viz., a few relatively thick striae separated one from another by two,

three, or more finer parallel striae, and the whole bound together by more or less distinct cross-striations." After referring to the fact that all insect scales have very narrow bases of insertion and noting that, at first sight, the photograph (v. B19, where the scale appears to be cut off irregularly) "seems to show a broad base of insertion," he suggests that "the insertion end of the scale may be distorted by the upturning of the slender stalk. In that case, the scale might easily belong to a Hepialid or Tineid moth."

"The length of your object is apparently 0·16 mm. The average length of a series of Hepialid scales which I studied some years ago was 0·15 mm., so that your object comes very close to this. I have not measured the average length of scales from the wings of *Charagia virescens* or any of the New Zealand species of *Porina*, but I should imagine they would be pretty close to this. The pink colour rather suggests to me a scale from the wing of a *Porina*."

The possibility of distortion (or actual fracture) of the stalk of the scale referred to by Dr Tillyard, turns to a very likely probability in the mind of one familiar with the comparatively rough treatment which a coal receives in the grinding and polishing processes. It is quite probable that during these processes the stalk was torn out completely, assuming of course that it was still in position when the scale found its resting place in the coal-forming debris.

When the scale was first seen emerging from the coal surface, it appeared that it might possess the rarer form of attachment in which the scale margins project backwards on either side of the true point of insertion (see photograph C in plate, which clearly shows this form in a scale from the forewing of *Vanessa gonerilla*), but it afterwards became fairly evident that the scale was of the more usual type and that the forked end was its distal end.

An examination of scales from Lepidoptera belonging to several families showed that normal insertion coupled with a "fish-mouth" distal end was quite common in the Sphingidae, and not uncommon in the Hepialidae. A photomicrograph of a scale from the forewing of *Sphinx convolvuli* (A in plate) is reproduced for purposes of comparison.

The striae shown in the scale from the coal correspond very closely with those of *Porina signata*, a scale from which insect is shown in photograph B of the plate. Using a lens the strioles, or joining-bars, connecting the main longitudinal striations, can be seen plainly.

Perhaps all that can be said fairly about the scale in the Glen Afton coal is that it belonged to one of the higher Lepidoptera. It seems quite possible, however, that it actually came from a *Porina* of Oligocene age, though proof there can of course be none.

Porina belongs to the Hepialidae, a family "of an undoubtedly primitive type," and at present "very well represented in New Zealand by twenty species, most of which are large and conspicuous insects."†

†Hudson, G. V.: *Butterflies and Moths of New Zealand*, (1928), pp. 359 and 357.

"As regards New Zealand, the fossil record"—i.e., of insects—"is almost a blank. Some fossil insects of Oligocene age were discovered many years ago by Mr Thomas Esdaile, who presented his collection to the Otago Museum. The insects, however, were never studied and remained undescribed, and the valuable collection appears to have been lost."*

It is an interesting instance of the "law of chance" that the next trace of fossil insects to be found in New Zealand should have been stumbled upon in the examination of a piece of coal—an examination most certainly not made with a view to finding insect remains.

ACKNOWLEDGMENTS.

The writer wishes to express his thanks to those who sent the coal to him for examination; to Dr R. J. Tillyard for his advice; and to Miss A. Castle, of the Dominion Museum, and Miss E. A. Plank, of Victoria University College, who were good enough to prepare mounted specimens of scales from the Hepialidae, Tineidae, and many other families.

The age of the Middle Waikato coal-measures was long a matter for controversy. They are now held to be definitely of Oligocene age. In his presidential address to the Geological Section, Fourth Science Congress of New Zealand Institute, January, 1929, Dr J. Henderson states:—"The coal-measures are of two types and were formed under conditions predominantly, either estuarine and fresh-water, or littoral and salt-water. The first type occurs in the neighbourhood of Huntly and consists of grey and yellow semi-refractory clays up to 300ft. thick which grade upward into, and are interbedded with, the blue clays of the Whaingaroa series. Near the base there are one or more thick seams of coal containing a very small amount of sulphur." . . . The "fresh-water coals are pre-Whaingaroa in age." (Henderson, J.; *Trans. N.Z. Inst.*, vol. 60, 1929, p. 276).

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*Tillyard, R. J.; *Insects of Australia and New Zealand.* (1926), p. 469.

Contemporaneous Faults in the Coal-Measures of the Waikato District.

By W. H. A. Penseler, M.Sc., B.E., A.O.S.M.

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Introduction.

In the course of coal mining operations in the Waikato district small faults are commonly encountered. The majority have a throw of a few feet only and are troublesome in mining chiefly because of the necessity of altering the grade of the trucking roads. The writer, from a study of some of these innumerable small faults underground in the mines of this district, is of the opinion that they are confined to the Coal Measure Series only and were formed practically contemporaneously with the deposition of the sediments. They are evidently a result of the slumping, assisted by the shrinkage and adjustment on settling, of the estuarine sediments during deposition, and therefore can be classified as " Contemporaneous Faults." Faults of similar origin have been recorded from other places (see Kendall, 1922, p. 61, and Firth, 1930, pp. 96-97), and the nomenclature adopted is that suggested by the text of Kendall's description.

In order that there may be no confusion as to the implication of the term " contemporaneous " this type of fault is here defined as being contemporaneous with the formation of a particular bed or several beds in a series and therefore confined to that series, but it is not necessarily contemporaneous with the formation of a single bed in this series. For example, the contemporaneous faults in the Coal Measure Series of the Waikato district, which displace the coal seam or seams, are to be regarded as contemporaneous with the deposition of the series, and, although it is possible for some faults to have taken place during the growth of the peat mass, the majority probably took place after the complete hardening of the peat mass to coal while the enclosing sediments were still soft. The faults therefore are preserved owing to the presence of a " brittle " bed (the coal seam) enclosed in soft beds (the unconsolidated muds) and are the result of the settlement of both types of bed under the conditions explained in this paper.

Permission to publish the portions of the mine plans shown in figs. 2, 3, and 4 was given by Mr A. Burt, Manager of Pukemiro Collieries, Ltd., and by Mr J. Watson, Superintendent of Taupiri Coal Mines, Ltd., to whom the writer extends his thanks, as well as to Messrs H. N. Davies and G. Mottram, mine surveyors at Pukemiro Colliery and Rotowaro Colliery respectively, for assistance in the collection of data on these faults.

ORIGIN OF JOINTS AND FAULTS IN COAL MEASURE SERIES.

The rocks forming the Coal Measure Series of Lower Oligocene Age in the Lower Waikato basin are in the main argillaceous. In places, fine sandstone lenses, bands of carbonaceous shale, and nodules or bands of bog iron ore are met with (as also, of course, the coal seams worked in the district), but the predominating type is a grey or brownish-grey claystone, locally known as "fireclay." It is a fresh-water series of rocks deposited in a wide estuary on subsiding folded Mesozoic greywackes and argillites, which previously had been planed into a gently undulating surface. The claystones have already been described in detail in another paper (Penseler, 1930B). They are commonly jointed and a discussion of these joints is included because of their genetic relation to the small faults.

JOINTS.

Two kinds of jointing may in general be noted, though it is often difficult to differentiate them. The first kind is represented by many inclined, more or less parallel joints in a thin bed, a foot or so thick, lying between unjointed or less jointed beds. It is probable that this kind of jointing is induced by pressure and by differential movement between the beds, and may therefore be regarded as a form of fracture cleavage (see Leith, 1923, pp. 148-158). Related to the fracture cleavage is the "schistosity," or folding and crushing on a minute scale, commonly observed in the black friable carbonaceous shales (locally known as "blaes") which occur usually in thin layers in the claystones. Similar instances of folding and deformation of a bed between two unaffected beds are illustrated by Grabau (1919, pp. 781-785). This deformation is due to pressure and horizontal movement. Folding does not occur in every instance; often the thin bed of "blaes" has merely a fine platy or "micaceous" structure—and therefore a greasy feel—each small plate or lamina being finely polished. In places there are thin layers of claystone which, through pressure and horizontal movement, have been crushed and are now almost plastic and can be crumbled in the hand.

The second kind of jointing is seen most commonly in the normal thick claystone overlying the coal. The claystone forming the roof of the coal seam is naturally that best available for examination, and is exposed underground particularly where pillars are being mined, in stone drives, and where falls of the roof occur. In most exposures examined the claystone is seen to be jointed in a rough form of small block "faults." The surfaces along these joints are finely polished, not scratched; but the joints are irregularly spaced and stand in various directions and attitudes. Joints may intersect, but more commonly one joint either dies out before reaching another, or is cut off by another joint crossing it at an angle. That the movement took place before consolidation of the sediment to its present state is shown by the absence of scratches or of any crushed material, and by the dying out vertically of the joints. When bedding of the claystones is present the joints are seen to merge vertically into small

monoclines and thence into undeformed rock. There is no evidence in the Coal Measure Series and in subsequent series of external forces such as would cause this jointing, and it is evident that shrinkage is the main cause of their existence.

A similar origin for this type of jointing was postulated by Leith (1923, p. 33) who, referring to joints related to the contraction of a crystallising and cooling mass of lava, said that, " Similarly, joints may be very abundant in flat lying, consolidated beds of sediments, which plainly have not been disturbed by great exterior forces. One of the causes in this case is doubtless the change in volume incidental to the drying and settling of the beds. Mud cracks are one manifestation of this process. Joints may die out above or below; there may be evidence that jointing in a given bed was complete before the next layer of sediment was deposited. They are likely to be especially abundant near the contacts of different beds or formations (a fact often noted by well-drillers in search of water)." He said further (op. cit., p. 50) that this " type of local tension jointing is developed by the drying out of a sediment, resulting in the formation of mud cracks and of shrinkage cracks on a large scale. The joints so formed lack regularity and persistence, vertically and horizontally." He quoted the flat lying sedimentary Palaeozoic beds of the Mississippi Valley, the many joints in which are probably due to the drying and settling of the formation. " The topography of the basement controls the settling to some extent, and therefore the distribution of the resulting joints. Accompanying the vertical joints caused by tension, there are horizontal joints caused by shearing, due to the differential expansion and contraction of the different layers. Mud cracks are often associated with cross breaks causing the upper layer to separate and curve up from the lower layers." No such horizontal joints have been seen in the shrinkage-jointed Coal Measure Series of the Waikato district unless the thin beds showing fracture cleavage and the contorted layers of carbonaceous shale may be a manifestation of this. It seems more likely that the cross breaks associated with mud cracks are due to rapid drying, which with buried sediments would be slow and gradual.

Shrinkage is not confined to the claystones. The peaty matter which now forms the coal underwent considerable reduction in volume, but it is difficult to estimate with any degree of accuracy how much shrinkage took place in the peaty mass after burial because the degree of compacting of the lower layers before burial would affect subsequent volume reduction of the whole mass. According to Ashley (1907), one foot of coal is formed from about 3½ feet of well compressed peat and so the amount of shrinkage would be at least 60 or 70 per cent. Kendall (1922, pp. 64-65), after quoting Lomax, and Stopes and Watson, believes " that the reduction in passing from the state of wet undisturbed peat will not be much less than 15 or 20 to 1." Shrinkage of the coal-forming material would have no effect on the underlying beds. The cleat in the coal is the internal effect of this shrinkage, and externally the overlying claystone would be affected with the formation of the shrinkage joints. The

assumption implied by this statement is that coalification of the peaty mass took place before induration of the clays and muds, and the writer agrees with the opinion expressed by Kendall: "The evidence points to the probability that the accomplishment of the greater part of the change from plant to coal took place while the measures were still unconsolidated, and were able to adjust themselves to the shrinkage of the contained masses of coal-stuff" (op. cit. p. 165, footnote). This early solidification of the peaty mass is important and will be referred to subsequently when discussing contemporaneous faulting.

It is possible that the shrinkage jointing in the claystones is confined to a layer of greater or less thickness lying next above the coal seam, in which case the cause of this jointing is undoubtedly the adjustment of the partly consolidated clays to the shrinkage of the vegetal matter. Even though some shrinkage or consolidation of the clays might have taken place before the vegetal matter was coalified both the amount and the rate of shrinkage in the two beds would be different, and the conditions would then be favourable for the production of the shrinkage jointing characteristic of the junction of different beds or formations, as noted by Leith (op. cit.). This type of jointing would also be developed at the junction of different varieties of claystone in the Coal Measure Series. The blocky nature of the claystone overlying the coal, a source of danger underground, is therefore considered to have this origin.

FAULTS.

In addition to shrinkage as a cause of this jointing, slumping or slipping of the beds under load may also give rise to joints or small faults, though here probably the effects would be greater, that is, small faults would be produced apart from joints as such. The slipping or slumping of a mass of unconsolidated sediment may again be an effect of the drying out of underlying sediments, assisted in most cases no doubt by gravity and by the weight of overlying sediments. Slipping of layers of sediments would in general be down an inclined floor or towards a lower level under the influence of gravity, and towards the centre of a basin where, owing to the greater thickness of accumulated detritus, the result of shrinkage would be greater. A cross section through such a basin would show the lower layers conforming more or less to the surface of the basin and becoming more horizontal as the upper beds are reached. A series of small slips or normal faults may be found on the side slopes of the basin. Similar effects are seen to-day in the sediments deposited round the mud lumps in front of the Mississippi delta where, according to Twenhofel (1926, p. 528), "at the surface and about the core of mud the strata are deformed, and fine examples of block faulting are said to be common."

The basal Waitemata Beds in Manukau County, Auckland, show shrinkage and slumping effects. "Evidence of minor faulting or down-sagging at or adjacent to steep contacts with the greywacke of the 'oldermass' is complete in several cases, but is explicable merely

by the shrinkage on consolidation and drying of a moderate thickness of beds." (Firth, 1930, pp. 96-97).

Slipping due to shrinkage of the clays, to slumping, and to the weight of overlying sediments may conceivably give rise to very large joints or small normal faults under favourable conditions imposed by situation on a sloping or uneven surface. Such faults would affect both claystones and coal, would be irregular, would die out vertically and horizontally, and would be confined to the Coal Measure Series. The overlying series of rocks would be undisturbed and would therefore show no evidence of the faulting below. The existence of such faults has already been noted. "Faults, overthrusts, and unconformities may as a rule be classed among what I have called the posthumous type of interference, though in many cases true faults appear to have achieved a portion of their total movement contemporaneously with the deposition of the seams, or during the interval between seam and seam. An illustration of a contemporaneous fault is found at the Barrow Colliery, near Barnsley, where, on the downthrow side of the fault and parallel with it, the Thorncliffe Thin Coal swells up from 3 feet to 5 feet 6 inches, and carries a strip of cannel absent elsewhere in the mine. Of a fault moving between seam and seam an example is furnished at Whitwood, where a lower seam is thrown to the extent of 60 feet while an overlying one is unbroken. The case of a fault affecting an upper and not a lower seam is noticed at Aldwarke Colliery." (Kendall, 1922, p. 61). A more general observation is that of Leith (1923, p. 75) who said: "Normal faults may be locally developed in nearly flat-lying sediments. Here the cause of tension may be shrinkage and settling due to drying and recrystallisation. A displaced layer is sometimes covered by a continuous layer of sediment, suggesting that the faulting was contemporaneous with deposition. Often no other causes are discernible, but it is not possible to exclude hypotheses of regional or deep-seated tension related to major earth movements." He gave no examples of these faults; and, as remarked before, there is no evidence to show that these faults could have been produced by any external forces, because they are confined to a particular series and all their properties can readily be explained from their origin as shrinkage and slip lines in this series.

Unfortunately, from the data available or ever likely to be available, there is no means of calculating the total shrinkage that the Coal Measure Series in the Waikato district has undergone. The total thickness varies from about 80 to 300 feet, and because many of the bores in this district did not reach the basement rock the different thicknesses of the undermeasures, as well as the contours of the basement rock, are not everywhere known. The old land surface was, however, a gently undulating one. From one to three thick seams of coal are present and the large shrinkage of this vegetal matter introduces another factor. Furthermore, the coal measure claystones are not uniform lithologically and show marked variations, the result of the characteristic lenticularity of these estuarine beds. From a study of the coal measures as a whole, sedimentation was in general continual, though diastems of greater or less magnitude

occurred as well as "hesitations" in the rate of subsidence, and during these periods some consolidation of the clays took place before they were affected by the loading of sediments subsequently deposited. The shrinkage of muds on solidification may amount to 20 or 50 per cent. or more (Twenhofel, 1926, p. 526), and during Coal Measure times in the Waikato district the deposited clays and muds were forced to adapt themselves to shrinkage by slumping, and probably flow, under various conditions imposed by the weight of overlying material and by an uneven floor. By uneven floor, the writer refers not only to the original basement Mesozoic rocks but also to subsequent surfaces of partly consolidated clays, which were not necessarily parallel to the original or to any later temporary floor.

Summarising then the mode of origin of these contemporaneous faults, they are the result of the slipping or slumping under load of dominantly argillaceous sediments. The movement is caused in the first place by the shrinkage of the clays on loss of water, but is assisted by the weight of overlying material. A necessary contributing cause is an underlying sloping surface of deposition, and so gravity plays an important part in causing the slumping. The strike of the faults would therefore follow the contours of such surface. Assistance to the movement would be given by different amounts of shrinkage caused by different thicknesses of sediment beneath the seam of "coal." Because the peat-like material would probably be coalified before much consolidation of the enclosing muds had taken place (see page 105), it is evident that these faults would occur principally as displacements or fractures of the coal seam or seams. The slumping or slipping movement might, in the muds, be absorbed as adjustment by flow, although it is possible that large joints or small faults, similar to the shrinkage joints described on page 103, might occur confined to the claystones only. Their formation would depend on the degree of consolidation of the muds. For obvious reasons all the contemporaneous faults seen are those which cause displacements of the coal seam or seams, but it is reasonable to regard these faults as being developed principally as fractures of the coal. Characteristically, these faults would have a variable amount of throw and would not be continuous over long distances. Contemporary faulting which took place during growth of the peat swamp and was caused by settlement of the underlying clays, would be characterised by a fracture or displacement of the undermeasures passing into the base of the seam without effect on the top of the coal. The seam on each side of the fault would be different in thickness and, although a step would be present on the floor of the seams, the roof would be continuous. Again, because every surface of deposition in the estuary did not necessarily remain parallel to the original surface, faulting at different periods would not necessarily follow the same lines or affect the same parts of the series. Thus, where two seams of coal occur, faults may be found in the upper seam and not in the lower, and vice versa, and their strike need not be the same in each case. By the time that the original basin-shaped depression had been more or less filled the irregularities would be smoothed over and the dips everywhere slight, so that there would now

not necessarily be the same conditions or reasons for contemporaneous faulting except perhaps where younger beds overlap on to an irregular surface. Therefore an overlying deposit might be unfaulted.

The main features of these contemporaneous faults are illustrated by the block diagram in Fig. 1. Probably any smaller faults lying at an angle to a larger fault have been developed as secondary slips, as shown in the lower right-hand section of the block.

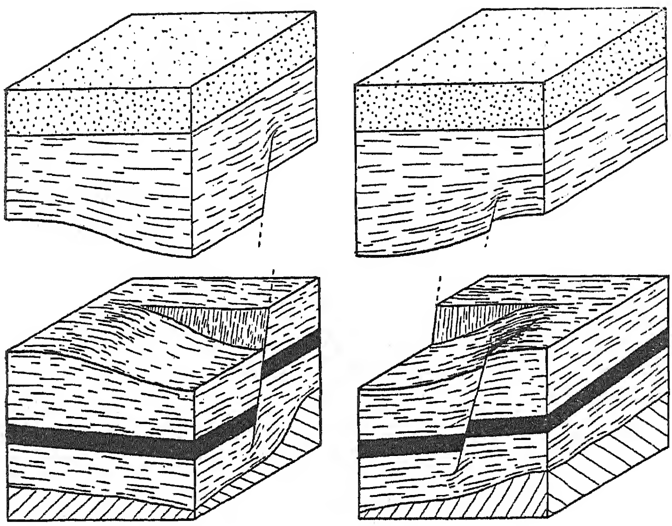


Fig. 1.—Block diagram, showing main features of a "contemporaneous" fault with possible development of a cross fault of similar origin.

Examples of Contemporaneous Faults.

The following descriptions are of contemporaneous faults which occur in the several mines of the Waikato district, and with which the writer has had personal experience. These coal mines are worked on the bord and pillar system, and an examination of the colliery plans does not always reveal the extent to which the small faults occur in the workings. As a rule, only the large block faults (formed during the Kaikoura orogeny at or about the close of the Tertiary period, and displacing all the rocks including the basement rocks) and the larger or more continuous of the contemporaneous faults are marked on the mine plans, and the recording of the many small faults shown in Figs. 2 and 3 is due to the detailed survey of these particular districts of the Pukemiro Colliery by Mr H. N. Davies.

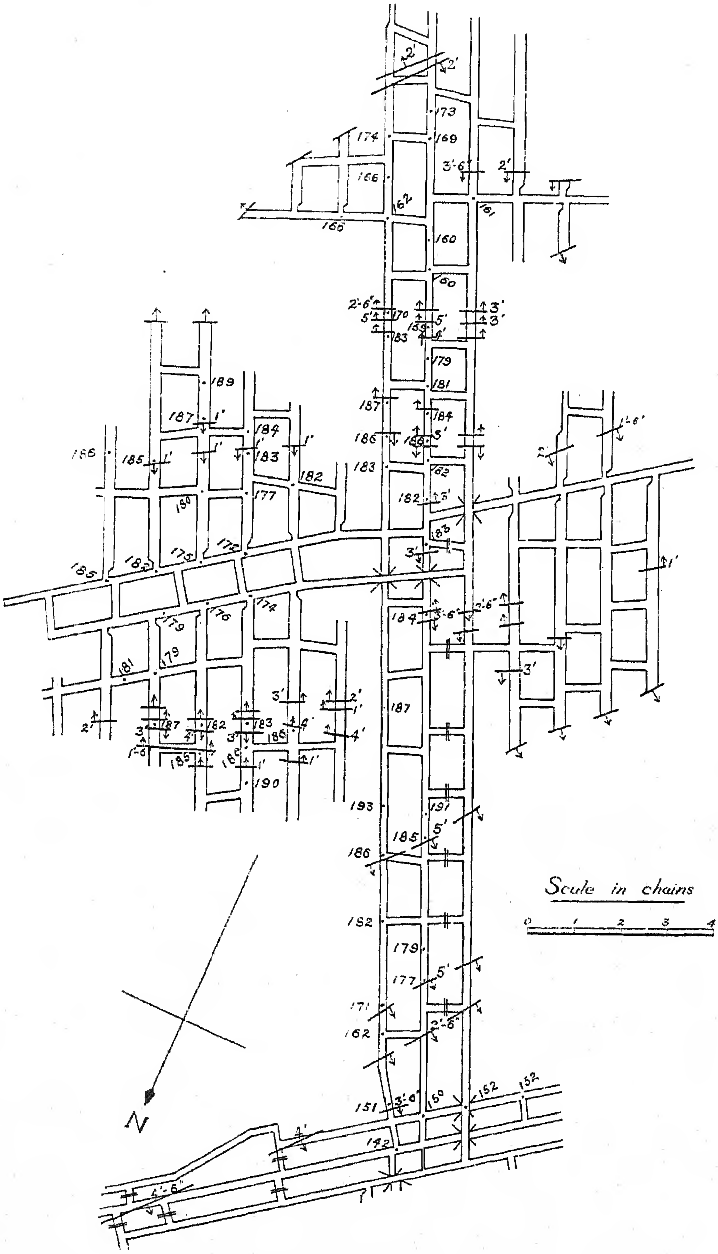


FIG. 2.—Plan of Horne's No. 2 Section, South Mine, Pukemiro Collieries, showing small faults with direction and amount of throw. Other numbers indicate height in feet above sea level.

All the contemporaneous faults seen are normal faults with a dip (variable) of about 50°. The majority have a throw of a few feet only (see Fig. 2), but faults with greater throw, up to 30 feet and perhaps more (see Figs. 3 and 4), are not uncommon. Faults are numerous where the seam dips comparatively steeply, and generally the displacement is "downhill," although it appears that, under some conditions, adjustment, or possibly re-adjustment, results in a small fault dipping in the opposite direction. These variations can be seen in Fig. 2, where can be seen also the lack of persistence laterally of some of the faults. In this part of the mine the general downhill dip of the faults should be noticed, and although no bores have been drilled to the basement rock it can be inferred from neighbouring bores that an undulation or projection of the basement rock occurs. During deposition and settlement the sediments slumped down the surface and the strike of the faults will therefore follow the contours of this old surface. Similar faults are found in almost flat-lying parts, though there they are not so numerous and commonly follow irregular or sinuous courses. A fault may be cut off by another meeting it at an angle (see Fig. 1), and it is not unusual to find that a fault occurring in one bord is absent in the neighbouring bords. The variable throw of these faults is therefore explained.

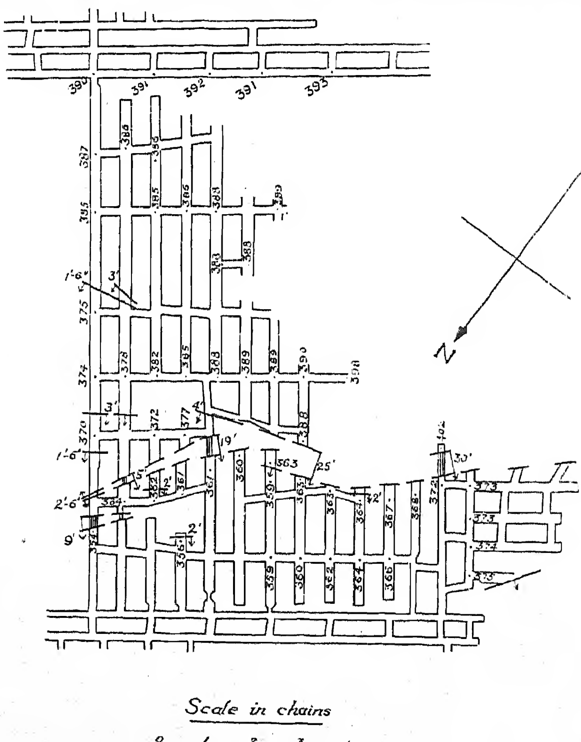


Fig. 3.—Plan of portion of Machine Bords Section, North Mine, Pukemiro Collieries, showing the variability of a large contemporaneous fault. Other numbers indicate height in feet above sea level.

Fig. 3 shows a larger contemporaneous fault which starts as a roll and increases to 30 feet in throw. The further behaviour of this fault is unknown. A stone drive or rise was put up as shown on the right of the plan and it was seen here that the fault extended into the claystones with the same rate of dip as it had in the coal. From its origin as a roll in the coal seam it may be concluded that this fault does not extend into the underlying basement rock.

That the coal-forming vegetal mass had been consolidated practically to its present form is shown by the fact that there is no change in the cleat right up to the fault plane. The coal also maintains its usual appearance with horizontal bedding of the lenticles of bright coal (see Penseler 1930A) and at the fault plane itself evidence of fracture in some comminution or crushing of the coal is commonly seen. The fault plane or zone is usually narrow (not more than an inch or two wide), filled with powdery matter, and called a "sooty-back" by the miners. A "sooty-back" usually indicates the presence of a step in the floor or roof, or both. Some of these faults seen at Rotowaro do not pass right through the seam and affect the claystone floor and lower part of the seam only (see page 107). In some places, the coal is crushed within a foot or two of the fault, but at others it is normal and clean right up to the fault and no crushed coal is present. When crushed, the coaly material may be cemented by the deposition of calcium carbonate from circulating solutions, and the writer has noticed, particularly with the large fault shown in Fig. 3, that the upthrow part of the seam was crushed and cemented with calcium carbonate, whereas on the downthrow side the coal was clean and not crushed. The claystone along the fault planes, where exposed, is polished or distorted by "drag" into the fault zone. Commonly some gouge is present. In the majority of the smaller faults a foot or so at the most of the claystone is exposed (usually on the floor because, where possible, coal is left to support the roof) and the extent or persistence of the faults into the claystone could not be determined. If, as is probable, the claystones were only partly consolidated when the faulting occurred, the faults would soon die out or the movement become distributed into a number of small slips, or even into a flow of the semi-plastic material, but with the large fault of Fig. 3 the fault, as already mentioned, was persistent for at least 30 feet below the coal on the upthrow side. From studies at Rotowaro, however, these faults must die out sooner or later in the claystones without affecting the basement rock, and upwards they would not pass out of the Coal Measure Series unless as an exception to the rule and under special circumstances.

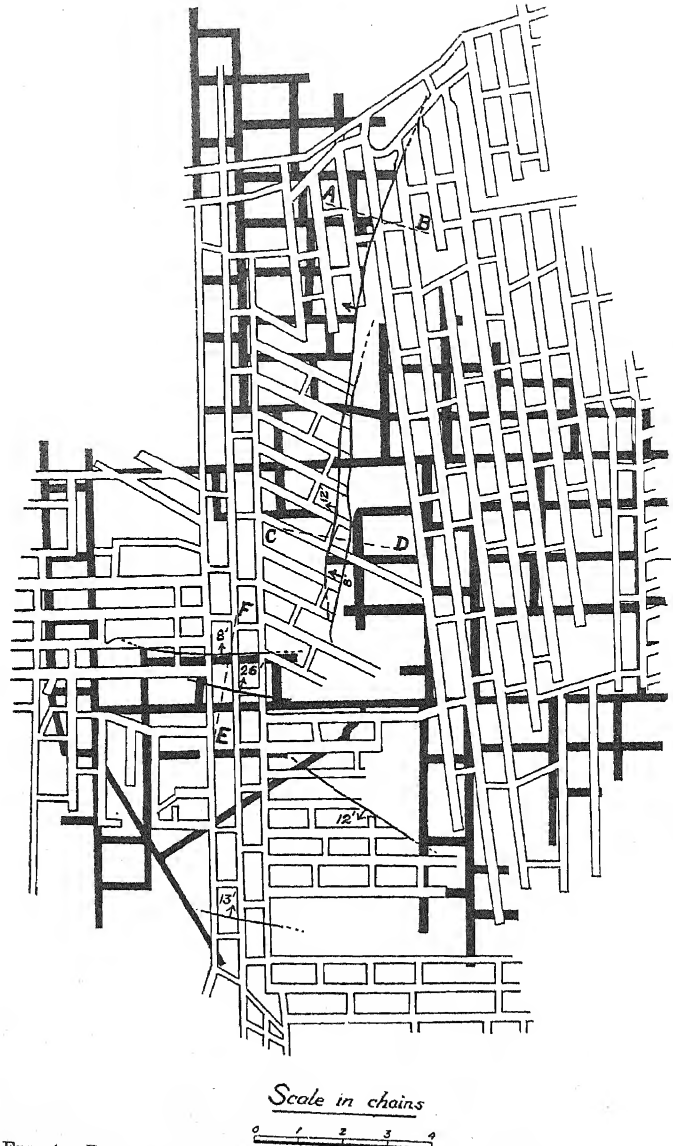


FIG. 4.—Part of Nos. 1 and 3 Mines at Rotowaro. Workings in upper seam (No. 1 Mine) shown white, and workings in lower seam (No. 3 Mine) shown black.

Part of the workings at the Rotowaro Collieries are shown in Fig. 4. Two seams of coal are present here and both are mined. Unfortunately, most of the workings shown (those in one seam underlying those in the other) are now inaccessible, particularly those in the upper seam, and only the larger faults were marked on the mine

plans. Many small faults do, however, occur, and on consideration of the non-persistence of the larger faults from one seam to the other it is evident that these smaller faults of small extent die out quickly above and below the coal seam.

Of the larger faults shown in Fig. 4, it might possibly be incorrect to say that they do not displace both seams, even if to only a slight extent in one seam, because one or more of the different smaller faults in a particular seam may represent either a continuation of the large fault or a distribution of the slip into several small, more or less parallel faults. On the other hand, if the large fault were not continuous, later faulting might have occurred in approximately the equivalent overlying beds because of the persistence of a sub-parallel sloping surface of deposition. In other words, although the cause of the faulting in each seam was the same, the two faults or sets of faults were not strictly contemporaneous with each other and are not continuous. It is impossible, for reasons already given and also because of the difficulty of differentiating the smaller faults, to correlate a large fault in one seam with smaller faults in the other. What evidence there is points rather to the discontinuity or rapid dying out of even the larger of these contemporaneous faults, and in any case it is quite clear that a 26 foot fault, for example, in one seam is not represented by a 26 foot fault in the other seam.

Section A-B

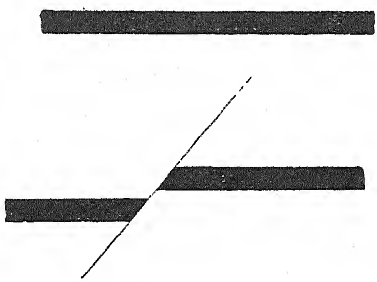


FIG. 5

Section C-D

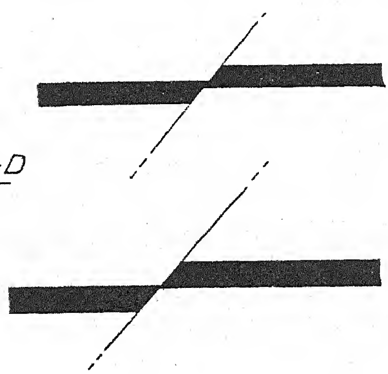
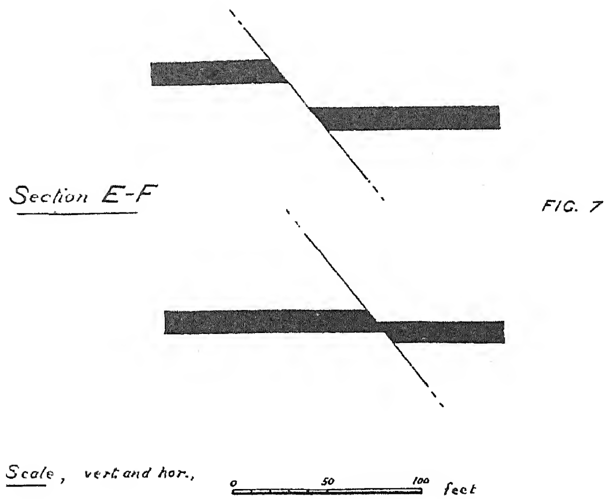


FIG. 6



Cross sections through the two seams illustrating these larger faults are given in Figs. 5, 6, and 7. None of the bores in this part of the coalfield was drilled to the basement rock—many not extending more than a few feet below the upper seam—and therefore the thickness of the claystone underlying the bottom seam is unknown. The thickness of claystone between the two seams is variable, as is the thickness of the coal, and because of these facts as well as because the full thickness of the coal is not always worked and a large fault is not always explored, the cross-sections are more diagrammatic than exact. The faults shown in sections A-B and C-D are interesting because they illustrate the occurrence of separate faulting at successive periods. The fault in the bottom seams has a greater throw and is more extensive than that in the upper. In fig. 7, the 26-foot fault in the upper seam is probably not continuous with the small fault in the lower seam, which as seen underground soon dies out laterally.

As at Pukemiro and in the other mines of this coalfield, the dip of these faults is in the same direction as the dip of the coal seam.

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Sclerodermaceae of New Zealand.

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THE Sclerodermaceae is a small family of fungi placed by taxonomists under the sub-class Gasteromycetes. The family is limited to the genera *Scleroderma* and *Pisolithus*, and is characterised by the method of development, simple peridium and absence of a definite capillitium.

In *Scleroderma* the mature plant consists of a simple, one-layered, tough and (usually) leathery peridium composed of intricately interwoven hyphae and projected basally into a short rooting base from which arise abundant rhizoids which attach the plant firmly to the substratum. The peridium encloses the gleba, which at maturity is pulverulent and composed of spores mixed with scattered hyphal fragments. Dehiscence is effected by the peridium rupturing irregularly into lobes at the apex, exposing the powdery spore mass, which is ultimately dispersed by wind. In some species, as the plant ages the lobes become revolute, giving to old specimens a stellate appearance; and in one, dehiscence is effected by an irregular apical mouth.

During the course of development, numerous tramal plates are formed, which are so arranged that the gleba presents a distinctly cellular appearance. As the plant develops these become absorbed gradually, until at maturity little remains but scattered fragments, save in individual plants of one or two species, where the plates partially persist and give to the gleba a veined appearance.

In *Pisolithus* the peridium is similarly organised, but the tissues become infiltrated and so altered as to become carbonous and brittle at maturity. The tramal plates therefore persist and form the feature separating the genus from *Scleroderma*. And dehiscence is effected by irregular breaking away of the peridium from the apex downwards, which exposes the persistent cells of the gleba and the enclosed spore masses which fill each cell.

Scleroderma Persoon ex Fries, *Syst. Myc.*, vol. 3, p. 44, 1829.

Scleroderma Pers., *Syn. Meth. Fung.*, p. 150. 1801, *pro parte*.
Sclerangium Lev., *Ann. Sci. Nat.*, ser. 3, vol. 9, p. 132, 1843.
Stella Mass., *Jour. Myc.*, vol. 5, p. 185, 1890.

Plant consisting of a firm, simple peridium which encloses the gleba, and is projected basally into a short rooting base from which arise numerous rooting rhizoids. Peridium of a single tough and pliable membrane, dehiscing by apical rupture into several lobes, which in old specimens often become revolute, or less frequently by an irregular apical stoma. Gleba pulverulent, of spores mixed with a few hyphal fragments. Spores globose, coloured, continuous. Basidia bearing from 1 to 5 spores, which are sessile or produced on short sterigmata.

Type Species: *Scleroderma aurantium* Pers.

Distribution: World-wide.

The number of species recorded is large, upwards of 60 being listed in the numerous volumes of Saccardo's *Sylloge Fungorum;* but as few earlier workers appeared to have had any clear idea as to the specific characters of the genus, it is improbable that there are more than about 10 valid species, the many others being synonyms of these or of species of *Mycenastrum* or *Pisolithus.* In New Zealand the genus is apparently represented by two species only, judging from the numerous collections I have examined.

The genus has proved a difficult one for the systematist, as most species have been based on characters now known to be too variable for specific delimitation. After an examination of some 95 collections from Australia and New Zealand I have come to the conclusion that the method of dehiscence, colour of the peridium and gleba, and nature of the surface of the peridium (characters commonly used in specific diagnosis) are alone specifically valueless, though, when considered in conjunction with other features, are useful aids in diagnosis; whereas the size and markings of the spores are much more reliable features. But the spores cannot be examined readily unless mounted in a suitable medium. I find a useful mountant to be a 50 per cent. solution of lactic acid in water, to which has been added 0·1 per cent. aqueous solution of analine blue; for if spores are mounted in this and heated to boiling point, their markings are rendered free from obscuring matter and may then be examined critically.

Most of the European species were erected by Persoon or Fries; but as they were based on variable characters, and spores were not considered, an interpretation of these species in the light of spore characters is possible only by reference to the work of Hollos (1904), where the spores were first accurately described. Consequently modern workers rely upon Hollos's interpretation of species erected by these earlier workers.

The two species present in New Zealand may be separated readily upon the following spore characters:—

Spores strongly reticulated .. .. .. 1. *S. Bovista.*
Spores covered with spines .. .. .. 2. *S. flavidum.*

1. **Scleroderma Bovista** Fries, *Syst. Myc.*, vol. 3, p. 48, 1829; emend. Hollos, *Gast. Ungarns,* p. 132, 1904. Figs. 1, 5.

S. texense Berk., in Hook. *Jour. Bot.,* vol. 4, p. 308, 1845.

Plants solitary or gregarious, to 4 cm. diameter, compressed globose, firm, somewhat plicate below, with a short rooting base and attached firmly to the substratum by numerous rhizoids. Peridium when dry tough, firm, to 0·5 mm. thick, dehiscing by irregular rupture of the apex, externally furfuraceous, or less frequently finely areolate apically, sulphur-yellow or more often bay brown or pallid umber, often somewhat vinaceous. Gleba at first violaceous, becoming umber;

tramal plates often partially persistent, yellow, hyphae with distinct clamp connections. Spores strongly reticulated, globose, 11-16 mmm., deep umber tinted with chocolate, reticulations to 3 mmm. tall.

Habitat: Growing amongst grass on sandy or cultivated soil.

Type Locality: Germany.

Distribution: Europe; North America; New Zealand. Auckland: Buried Village, Wairoa, 2/27, J. B. Cleland, G.H.C.; Whakarewarewa State Forest Nursery, 5/28, G.H.C. Taranaki: Botanical Gardens, New Plymouth, 2/27, G.H.C. Wellington: Wanganui, 4/25, D. W. McKenzie; Palmerston North, 5/30, G.H.C.; Weraroa, 3/25, J. C. Neill.

The characters of the species are the strongly reticulated spores, thin but firm, externally smooth peridium, and frequent persistence of portions of the tramal plates, the hyphae of which possess abundant clamp connections.

In the thermal regions specimens are more lax and yellow than those from other localities, but are otherwise identical. The species is often found growing associated with healthy roots of *Pinus radiata* in the State Forest Nursery at Rotorua, and has been found similarly with strawberry plants at Palmerston North. It is probable therefore that it forms a mycorrhiza with the former (and possibly too, the latter) host, since Peyronel (1922) found "*S. vulgare*" formed mycorrhiza with roots of *Larix decidua* and *Quercus robur* in Italy.

2. **Scleroderma flavidum** Ellis and Everhart, *Jour. Myc.*, vol. 1, p. 88, 1875. Figs. 2, 6, 7.

S. caespitosum Lloyd, *Myc. Notes*, p. 1159, 1922.

Plants solitary or gregarious, sometimes caespitose, growing half buried until maturity, to 5 cm. diameter, firm, pyriform or subturbinate, often lobed, usually plicate below, contracting into a short rooting base, which is attached to the substratum by numerous rhizoids, or sometimes compacted into a conspicuous, stem-like structure. Peridium when dry tough, leathery and seldom brittle, to 1 mm. thick, dehiscing by irregular rupture into several lobes, which in weathered plants frequently become recurved and stellate; pallid or bright yellow, or as often dingy brown, sometimes vinaceous, finally areolate above, sometimes almost smooth. Gleba at first violaceous, becoming ferruginous or umber brown; tramal plates sometimes partially persistent, when yellow. Spores globose, 10-14 mmm., coarsely and densely echinulate; spines acuminately pointed, somewhat narrow at their bases, to 1·5 mmm. long.

Habitat: Growing on sandy soil, or partially buried in clay or rock cuttings.

Type Locality: New Jersey, North America.

Distribution: North America; Africa; Australia; New Zealand. Wellington, 5/22, J. B. Cleland.

forma *macrosporum*.

Spores large, commonly 14-16 mmm., sometimes attaining a diameter of 19 mmm., and more coarsely echinulate, spines often appearing in the form of soldered warts. Otherwise identical with the typical form.

Distribution: Australia; New Zealand. Auckland: Waitakere Ranges, 9/21, D. Miller; Rotorua, 7/23, G.H.C. Wellington: Botanical Gardens (9 collections), G.H.C. Nelson: Mapua, 2/20, G.H.C. Otago: Deborah Bay, 9/26, Miss H. K. Dalrymple; Dunedin, 5/22, 9/22, 7/23, Miss H. K. Dalrymple.

The characters of the species are the firm, areolate, leathery and relatively thick peridium, and the echinulate spores. Two types of spores are present in the collections examined. In the typical form the spores are commonly 10-14 mmm. in diameter, and the spines to 1·5 mmm. long; whereas in the other the spores are commonly 14-16 mmm., and in extreme cases may attain a diameter of 19 mmm., and the spines are larger, and often aggregated into the form of soldered warts. The latter is the common form in New Zealand, and is about equally distributed with the typical form in Australia. The typical plant agrees closely with the description of the species published by Coker and Couch (1928, p. 162), who have examined authentic specimens of *S. flavidum.*

Excluded Species.

Lloyd (*Letter 8*, p. 2, 1905; *Letter 67*, p. 2, 1918; and *Myc. Notes*, p. 1160, 1922) has recorded *Scleroderma cepa* Pers., *S. Geaster* Fr. (*Myc. Notes*, p. 1186, 1923) and *S. verrucosum* Pers. (Lyc. Aus., p. 15, 1905) from New Zealand. But from specimens at hand, and Australian collections named by him, I am convinced these records are based on misdeterminations of *S. flavidum.* Lloyd ignored the spore characters, and therefore was unable to distinguish (as the numerous Australian collections he misnamed show) between *S. flavidum*, *S. cepa*, *S. Bovista*, *S. Geaster*, and *S. aurantium.*

Pisolithus Albertini and Schweinitz, *Consp. fung. Lusatiae sup. Nisk crescent.*, p. 82, 1805.

Scleroderma Pers., *Syn. Meth. Fung.*, p. 151, 1801, *pro parte.*
Polysaccum DC. et Desp., *Rapp. Voy. bot. l'Ouest Fr.*, vol. 1, p. 8, 1807.
Pisocarpium Link, *Mag. Ges. nat. Freunde Berlin*, vol. 3, p. 33, 1809.

Plant consisting of a peridium supported upon a (usually) strongly developed, persistent rooting base. Peridium a single, thin, brittle and membranous layer, flaking away irregularly from the apex downwards. Gleba divided into polygonal cells by the persistent tramal plates; cells filled with the pulverulent spore mass, capillitium absent. Spores coloured, globose, verrucose. Basidia bearing 4-6 spores on short sterigmata.

Habitat: Growing half buried in the ground in sandy soils.

Type Species: *Scleroderma tinctorium* (Mich.) Pers.

Distribution: Europe; North America; Africa; East Indies; Australia; New Zealand.

The persistent, carbonous and brittle tramal plates and the brittle membranous peridium, which flakes away irregularly at maturity, are the characters of the genus separating it from *Scleroderma.* The usually persistent and well developed sterile base

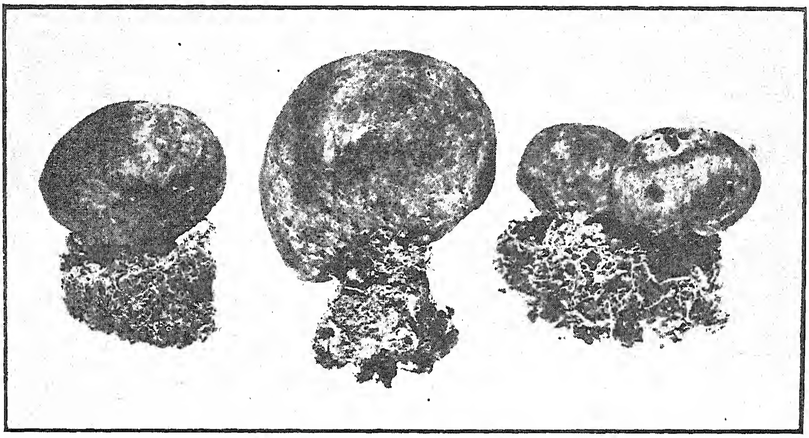

FIG. 1—*Scleroderma Bovista* Fr. Natural size. Gregarious plants on the right. Note the almost smooth exterior of these specimens.

[*H. Drake, Photo.*

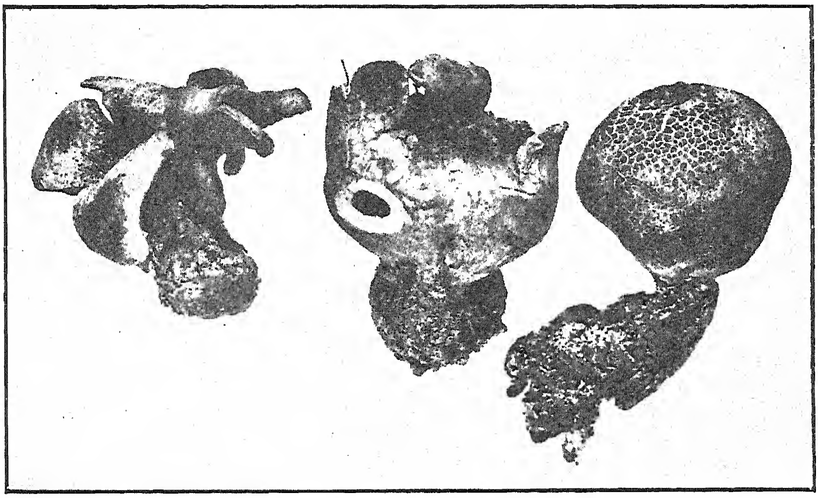

FIG. 2.—*Scleroderma flavidum* E. et E. Natural size. Plant in the centre typical form, on left weathered specimen showing stellate method of dehiscence, and on right a plant with areolate peridium.

[*H. Drake, Photo.*

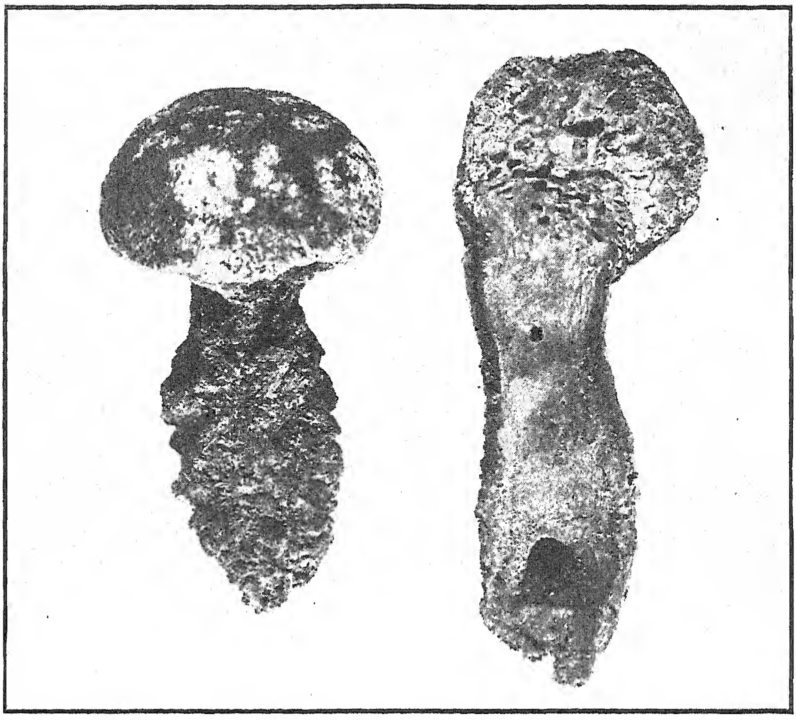

FIG. 3.—*Pisolithus tinctorius* (Pers.) C. et C. Natural size. Plant on right sectioned to show the persistent glebal chambers filled with spores. Note the stout rooting base.

[*H. Drake*, *Photo.*

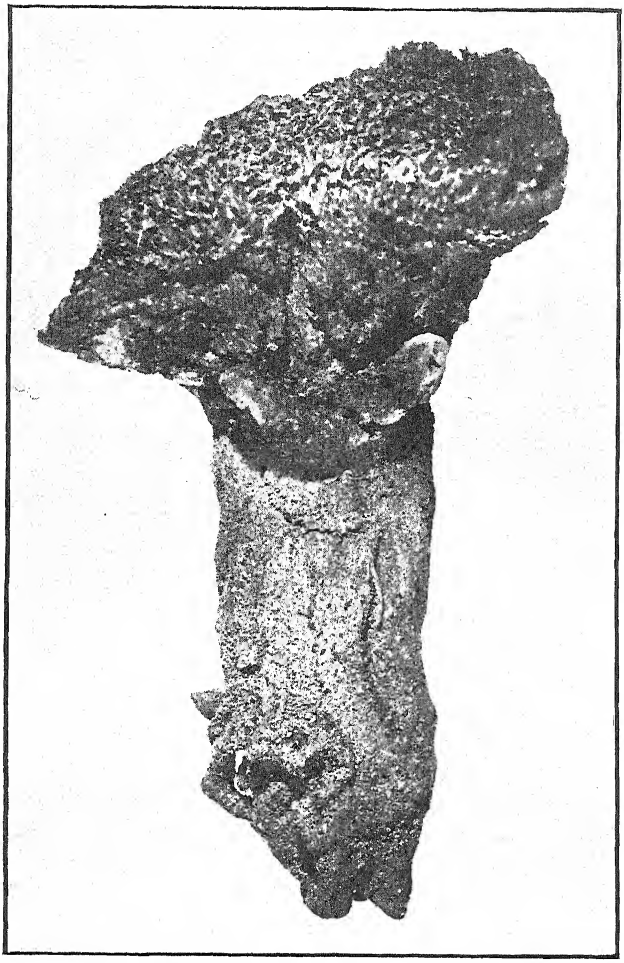

Fig. 4.—*Pisolithus tinctorius.* Reduced one-third. A plant from which the greater part of the gleba has been dissipated. Note the persistent carbonous dissepiments of the gleba and the stout, persistent rooting base.

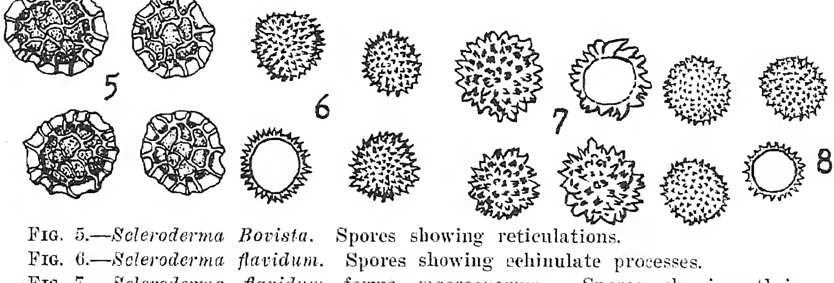

Fig. 5.—*Scleroderma Bovista.* Spores showing reticulations.

Fig. 6.—*Scleroderma flavidum.* Spores showing echinulate processes.

Fig. 7.—*Scleroderma flavidum* forma *macrosporum.* Spores showing their larger size and the coarse nature of the spines.

Fig. 8.—*Pisolithus tinctorius.* Spores showing the echinulate processes. (Original) Spores x 1000.

is also a characteristic feature, as it often persists in the soil long after the gleba has been dispersed. The genus contains two, or possibly three valid species, and is represented in New Zealand by the widely distributed species described below.

Pisolithus tinctorius (Micheli ex Persoon) Coker and Couch, *Gast. East. United States and Canada*, p. 170, 1928. Figs. 3, 4, 8.

Scleroderma tinctorium (Mich.) Pers., *Syn. Meth. Fung.*, p. 152. 1801.
Pisolithus arenarius Alb. et Schw., *Conspectus*, p. 82, 1805.
Polysaccum crassipes DC. et Desp., *Rapp. Voy.*, vol. 1, p. 8, 1807.
P. Pisocarpium Fries, *Syst. Myc.*, vol. 3, p. 54, 1829.
P. australe Lev., *Ann. Sci. Nat.*, ser. 3, vol. 9, p. 136, 1848.
P. marmoratum Berk., *Jour. Linn. Soc.*, vol. 13, p. 155, 1872.
P. album Cke. et Mass., *Grev.*, vol. 20, p. 36, 1891.

Plant decidedly variable in size and shape, from 3 to 18 cm. tall, to 10 cm. diameter, with (seldom without) a firm, carbonous, well developed rooting base. Peridium a single layer, at first smooth, shining and pallid white or ochraceous, becoming brown or black, finally breaking away irregularly from the apex. Gleba divided into numerous polygonal or lenticular chambers, which are larger above and peripherally, unequal in size and shape, dissepiments carbonous, firm but brittle; chambers occupied with the pulverulent spore masses, ranging in colour from ochraceous to umber brown, sometimes tinged purple. Spores globose, 7-12 mmm. (commonly 7-9 mmm.), epispore thin, 0·5 mmm., ferruginous, covered with fine spines, which may attain a length of 1 mmm.

Type Locality: Europe.

Distribution: That of the genus. Auckland: Whakarewarewa, 2/27, J. B. Cleland, G.H.C.; Geyser Valley, Wairakei, 8/30, G.H.C.

In New Zealand the species appears to be confined to the thermal regions of the North Island, but is abundant throughout Australia, and apparently equally common in Africa, North America, and Europe.

Specimens differ greatly in size, shape, colour of the exterior, size and shape of the glebal cavities and nature of the rooting base, the only constant feature, in fact, being the spores. Most of these variants have been named at one time or another, usually from collections of single specimens; but examination of dozens of collections from Australia has led me to the opinion that it is not possible to separate any form as there are so many known intermediates as to make specific delimitation impossible. The specific name is derived from the fact that water extracts from the plant a yellow pigment which in Europe has been used by the peasants as a dye.

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On the New Zealand Lamprey, *Geotria australis* Gray. Part III. The Loss of the Mid-gut Diverticula of the Ammocoetes Stage at Metamorphosis.

By F. G. Maskell, Ph.D., Lecturer in Zoology, Victoria University College, Wellington, New Zealand.

[*Read before the Wellington Philosophical Society, 24th July, 1929; issued separately, 30th September, 1931.*]

1. Introduction.

In the preceding paper (Part II) of this series, the writer described a pair of mid-gut diverticula found in the *Ammocoetes* stage of *Geotria australis*. These diverticula appear to be unique in kind, since they are not known in any other lamprey, nor have they been described before in *Geotria* (*Ammocoetes* stage). They are characterised by the presence in their walls of glandular cells, which seem to be comparable with the exocrinous pancreatic cells of Vertebrates. Further, in *Geotria* no trace of these diverticula is to be found after the completion of metamorphosis by the *Ammocoetes*. It thus becomes a matter of interest to follow their fate during the process of metamorphosis.

During the months of January and February in 1928 and 1929, specimens undergoing metamorphosis, about twenty-five in all, were collected from various rivers in the Wellington district. After examination of this material, nine specimens were selected and these will be described below to illustrate representative stages in the reduction of the diverticula and in the changes in associated organs.

The specimens were dissected and the complex of organs in question drawn and later sectioned. The serial sections served to elucidate some of the finer points, which could not be made out in dissection. Again I am indebted to Professor H. B. Kirk for his helpful criticism.

2. Description of Stages.

Stage 1.—This stage represents the condition, typical of the *Ammocoetes*, before any signs of metamorphosis have appeared. The figures (Figs. 1a and 1b) are taken from a 9 cm. *Ammocoetes*. As this condition has been fully described in Part II of this series, only the essential points are referred to here.

The two mid-gut diverticula, structures peculiar to the *Ammocoetes* stage of *Geotria*, originate at the junction of oesophagus and mid-gut. The left diverticulum is about half the length of the

oesophagus and lies alongside it. Into this diverticulum, upon its dorsal surface and near its anterior end, opens the bile-duct. The right diverticulum is short and concealed in dorsal view by the posterior portion of the liver. A gall-bladder is present in the liver. The mesenteric artery crosses the oesophagus dorsally in close relation to the bile-duct and then runs alongside the left diverticulum, finally entering the spiral fold. The spiral fold starts in the mid-ventral line at the junction of oesophagus, diverticula, and mid-gut. The gut-vein runs dorsal to the gut on the side opposite to the spiral fold. A short distance posterior to the junction, it receives a large branch from the dorsal wall of the mid-gut and then continues forward as the portal vein to the liver, in which organ it breaks up.

Stage 2 (9·5 cms. specimen).—This (Fig. 2) represents a stage in early metamorphosis. The left diverticulum is somewhat reduced in length, the right considerably reduced. The bile-duct still retains its opening into the left diverticulum, and the gall-bladder is present. In the substance of the liver, just beneath its dorsal surface and about half-way down its length, are some conspicuous venous lacunae, not shown in the drawing, but noticeable in sections.

In other features this specimen resembles fairly closely stage 1.

Stage 3 (10 cms. specimen).—In this specimen (Fig. 3) the junction is no longer found at the same level as the posterior tip of the liver, but some distance anterior to this. Further reduction of the left diverticulum is noticeable; it is now about half its original length and its anterior half overlies the oesophagus instead of being alongside it (compare Fig. 1a). The right diverticulum is very short, having a separate lumen for seventeen sections only (each section seven microns thick); it is now ventral to the oesophagus. The bile-duct opens into the anterior tip of the left diverticulum, instead of upon its dorsal surface. The gall-bladder, although reduced, is still evident in sections. The spiral fold begins at the junction, but on the left side now. The new portal vein, which is to replace the old one, can be traced in sections at this stage. It can be followed from the left diverticulum forwards, across the oesophagus in close relation with the mesenteric artery and bile-duct, to the venous lacunae already noted in stage 2 in the dorsal surface of the liver.

This new portal vein is found later to be continuous with the vein of the spiral fold (intra-intestinal vein), and may be regarded as an anterior extension of this latter. The old portal vein is still present.

Stage 4 (10·1 cms. specimen).—The junction it situated further forward than in stage 3 and the left diverticulum is very short (Fig. 4). The right diverticulum has a separate lumen in only six sections (these sections, and all others, seven microns thick each) and lies partly ventral to the oesophagus. The bile-duct is short and transversely placed; its opening into the left diverticulum is evident in sections. The gall-bladder with a much reduced lumen is also

evident in sections. The spiral fold now begins on the left side. The new portal vein may be traced in sections from the spiral fold, alongside the left diverticulum, across the oesophagus and into the liver. The old portal vein is present.

It will be obvious from the changes in position of right diverticulum and spiral fold, and from the forward movement of the junction, that a process of spiral rotation of the gut is beginning. It appears from stages 3 and 4 that the left diverticulum may lag behind at first in this process, but in the following stage (intermediate between 4 and 5) the left diverticulum has rotated through an angle of 90°, just as right diverticulum and spiral fold have.

Here follows a specimen, which is intermediate between stages 4 and 5. The liver region was fixed and sectioned, but not drawn, hence it can be described only from serial sections. The specimen was 9 cms. long and represents the only one actually caught with the diverticula respectively dorsal and ventral to the oesophagus. In this intermediate stage the left diverticulum is short, and throughout its length is dorsal to, i.e., overlies the oesophagus, instead of being alongside it. The right diverticulum is now ventral to the oesophagus and has a separate lumen in fourteen sections. The spiral fold starts on the left side. Gall-bladder and bile-duct are present.

Stage 5 (10·1 cms. specimen).—The junction (Fig. 5) is found in about the same position as in stage 4. The rotation of the gut has progressed so far that the originally left diverticulum now lies on the right side of the oesophagus and the originally right diverticulum on the left side. The left diverticulum has crossed the oesophagus dorsally, the right has crossed the oesophagus ventrally. The left (now right) diverticulum is about the same length as in stage 4.

The right (now left) diverticulum is represented in this specimen as a mass, RD, visible to the naked eye, but found, when sectioned, to contain no lumen and to consist mainly of islets or follicles of Langerhans. These islets are referred to more fully in the summary. However, in three other specimens at the same stage, the right (now left) diverticulum shows an independent lumen in from seven to fourteen sections. The very short bile-duct is now on the right side of the oesophagus; of the four specimens at this stage, one shows the bile-duct clearly opening into the left (now right) diverticulum, in the other three this opening can no longer be seen. The gall-bladder is present with a reduced lumen. The spiral fold begins at the junction in the mid-dorsal line; in it run the new portal vein (dorsal) and the mesenteric artery (ventral).

The new portal vein leaves the spiral fold, accompanies the mesenteric artery as far as the anterior tip of the left (now right) diverticulum and then enters the dorsal surface of the liver. The old portal vein is present and slightly dilated at its entrance into the liver.

Stage 6 (10·1 cms. specimen).—The junction (Fig. 6) is nearer the anterior margin of the liver than in stage 5. The left (now right) diverticulum possesses an independent lumen during forty

sections; it tends to lie partly ventral to the oesophagus. The right (now left) diverticulum has an independent lumen in three sections; it now lies dorsal to the oesophagus. A small gall-bladder is present. Traces of the bile-duct persist, but there is no continuous lumen. The spiral fold begins at the junction near the mid-dorsal line and slightly to the right; a little farther back it lies more to the right side.

The new portal vein and the mesenteric artery are as in the preceding stage. The old portal vein persists; the anterior tributary, which it receives from the mid-gut, as it enters the liver, probably represents the tributary shown in Figs. 1, 2, and 4. This tributary could not be made out in Figs. 3 and 5.

Stage 7 (Specimen not measured).—This specimen (Fig. 7) appears very similar to stage 6, but serial sections reveal several advances. A small gall-bladder is still present, but it is lined by a tall columnar epithelium and its lumen is filled by a coagulum. There is no trace of the bile-duct. The diverticulum, originally on the left, later on the right (Figs. 5 and 6) is now ventral to the oesophagus and has a lumen in one section only. The originally right, later left, diverticulum is now dorsal to the oesophagus; it shows a lumen in three sections. The spiral fold begins on the right side; farther back it is more ventral in position.

Mesenteric artery, old portal vein and new portal vein are as in stage 6.

The future insular organ, IO, a mass of islets or follicles of Langerhans, is indicated on the left side at this stage.

Stage 8 (9·8 cms. specimen).—In this stage (Fig. 8) the junction of oesophagus and mid-gut occurs at about the level of the anterior margin of the liver.

There are no traces of diverticula, gall-bladder, or bile-duct. The spiral fold begins in the mid-ventral line; in it runs the mesenteric artery. Beneath the mesenteric artery and attached both to spiral fold and to dorsal surface of liver, is the new portal vein. The portal vein thus attaches the mid-gut to the dorsal surface of the liver.

Remnants of the old portal vein still persist, P.V.

Sections show that the posterior part of the oesophagus is now solid, with the exception of a few vacuoles in it; the animal must therefore be incapable of feeding. This posterior solid portion projects back a short distance into the lumen of the mid-gut; it is, as it were, being swallowed by the mid-gut.

Stage 9 (9·3 cms. specimen).—This is the *Macrophthalmia* stage; metamorphosis is complete, both externally and internally (Fig. 9). The junction of oesophagus and mid-gut is found above the pericardium and before the anterior margin of the liver. The oesophagus, provided now with a lumen, appears as if invaginated for a short distance into the right side of the most anterior portion of the mid-gut, into which it opens. The spiral fold commences in the mid-ventral line.

The liver is more or less flattened on its dorsal surface; it is much elongated compared with earlier stages; the intestine lies in a slight depression (concavity) on its dorsal side; the liver throughout its length is attached to the ventral wall of the intestine; this attachment is effected by the new portal vein, which lies below the intestine (spiral fold) and above the liver, but attached to both.

The mesenteric artery originates from the right side of the dorsal aorta at about the level of the insular organ, runs parallel with the right anterior dorsal prolongation of the liver, enters the substance of the liver and finally, the spiral fold.

No traces of diverticula, gall-bladder, or bile-duct are to be found, nor any remnants of the old portal vein.

The islets of Langerhans form now a compact organ (insular organ of Cotronei, 1927), at the left side of the oesophagus, just before it opens into the mid-gut.

In *Geotria* there are no indications of dorsal and ventral (Krause 1923) or cranial and caudal (Keibel 1927, Boenig 1928, 1929) portions of this organ, such as have been described in European lampreys. Here the follicles or islets of Langerhans form a single compact organ.

3. Summary.

Metamorphosis of the *Ammocoetes* of *Geotria* occurs in New Zealand (Wellington district) during January, February, and March, and usually when a length of about ten centimetres has been reached. The changes which take place during metamorphosis in the region of the liver are summarised below.

(a) The mid-gut diverticula, peculiar to the *Ammocoetes* stage of *Geotria,* become gradually reduced and finally disappear completely as such. The glandular cells, exocrinous pancreatic cells, which characterise the diverticula and which were described in Part II of this series, are lost also, of course, in this process. During the reduction of the diverticula, however, islets or follicles of Langerhans (referred to below) are budded from their walls.

(b) Before metamorphosis, the oesophagus joins the mid-gut near the posterior tip of the liver; after metamorphosis, this junction is at the level of the anterior margin of the liver.

(c) In the liver region, a spiral rotation of the gut occurs in such a way that (1) the originally left diverticulum appears to cross the oesophagus dorsally, coming to lie first on the right side of, but later ventral to the oesophagus; (2) the originally right diverticulum crosses the oesophagus ventrally to the left side, later becoming dorsal in position.

(d) The spiral fold in the *Ammocoetes* begins in the mid-ventral line at the junction of oesophagus, diverticula, and mid-gut. During metamorphosis, as a result of the forward spiral growth of the mid-gut, it begins successively (1) on the left side; (2) dorsally; (3) on the right side; and finally (4) in the mid-ventral line again (metamorphosis complete), thus having completed a full

turn and also having advanced considerably further forward on account of the spiral nature of the turn.

(e) The mesenteric artery in the *Ammocoetes* crosses the oesophagus dorsally from right to left and accompanies the left diverticulum before entering the spiral fold, which begins at the junction near the posterior tip of the liver. After metamorphosis, this artery enters the spiral fold from the right side and near the anterior border of the liver, where the junction is now situated.

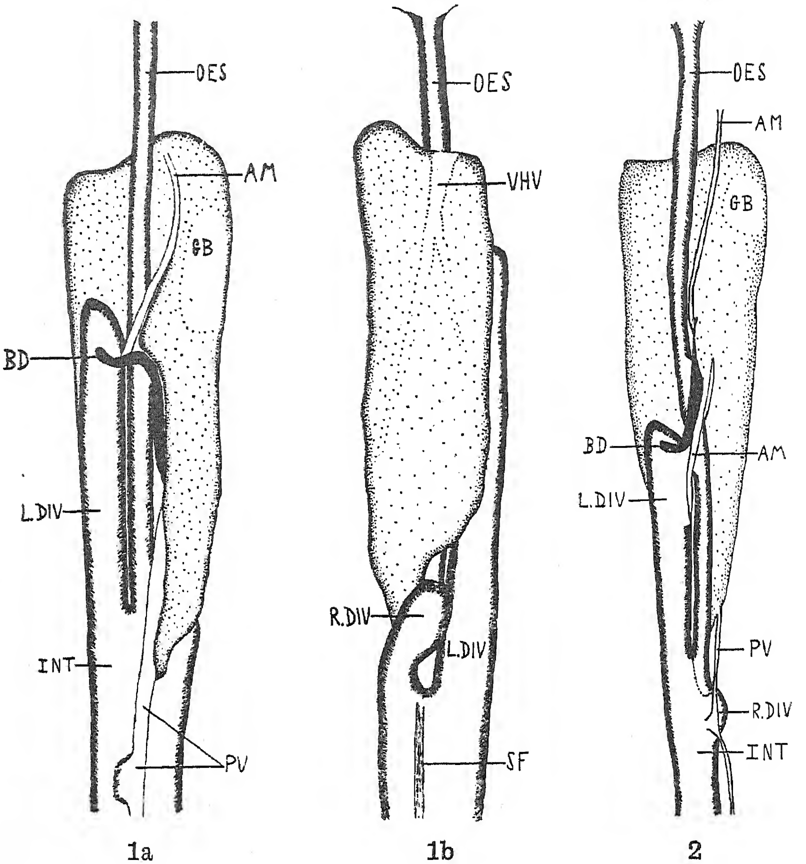
(f) The bile-duct, which at first (*Ammocoetes*) crosses the oesophagus from right to left in close relation with the mesenteric artery and opens into the left diverticulum, is later found much reduced in length and on the right side only (Fig. 5). Finally, it disappears completely.

(g) The gall-bladder is gradually reduced in size and finally completely lost. The epithelium lining the gall-bladder is (1) much flattened in young *Ammocoetes*; (2) cubical to columnar in large *Ammocoetes*; (3) composed of tall columnar cells in the second half of metamorphosis.

(h) The liver increases considerably in length and its shape somewhat alters.

(i) A new hepatic portal vein is substituted for the old one. In the *Ammocoetes* the gut vein (sub-intestinal vein) runs alongside the mid-gut and receives a large tributary from the dorsal wall of the mid-gut a short distance behind the junction (Fig. 1a). From here it continues forward as the portal vein, entering the posterior tip of the liver. Sub-intestinal vein and portal vein are lost during metamorphosis. The vein of the spiral fold (intra-intestinal vein) forms the new portal vein. During the earlier stages in metamorphosis it may be followed (in serial sections) from the spiral fold forward, alongside the left diverticulum and across the oesophagus in close relation with bile-duct and mesenteric artery to the dorsal surface of the liver. After rotation, it enters the liver direct from the spiral fold.

(j) The islets or follicles of Langerhans are microscopic, hence are not seen in dissections and are not represented in the drawings. Only towards the close of metamorphosis, when the islets become closely aggregated, do they form a mass, IO, the Insular Organ (Cotronei 1927), visible to the naked eye (Figs. 7, 8, and 9). Thus, at the completion of metamorphosis the islets form a single compact organ, which is embedded on the left side in the wall of the gut just before the junction of oesophagus and mid-gut (Fig. 9). As indicated before, there are no signs of separate cranial and caudal portions of this organ, such as are found in European genera after metamorphosis. During metamorphosis the number of islets is considerably increased by the proliferation of fresh islets from the epithelial walls of both diverticula in the region of the junction. As this paper deals mainly with macroscopic features, I have not attempted a detailed account of the islets.



FIGS. 1a AND 1b.—Dorsal and ventral views of dissections to show diverticula, oesophagus, liver and associated organs in the *Ammocoetes* stage (9 cms. specimen) before metamorphosis.

O E S = oesophagus. A M = mesenteric artery.

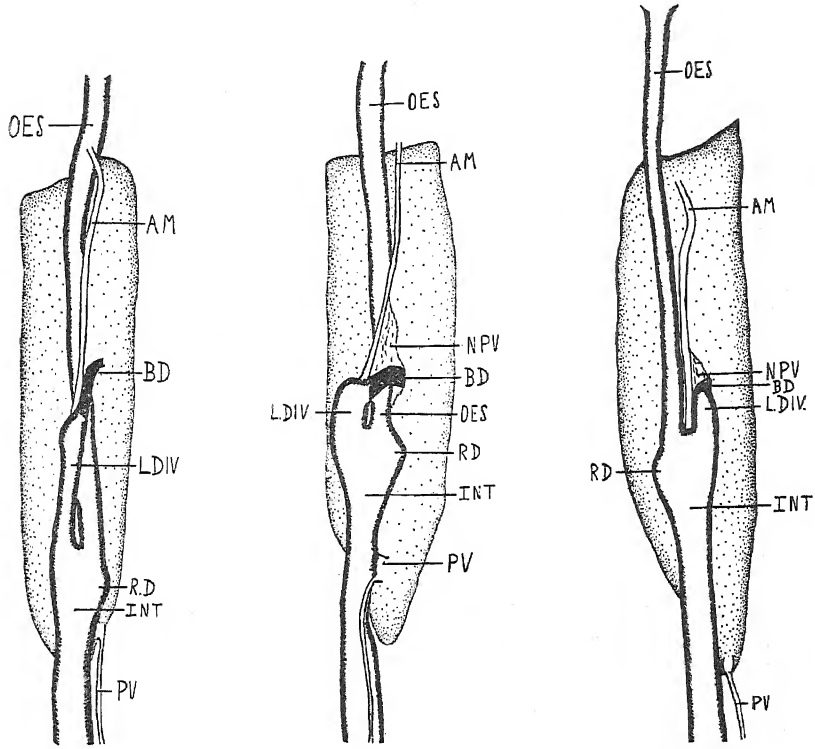
G B = gall-bladder. B D = bile-duct.

L. DIV = left diverticulum. R. DIV = r. diverticulum.

P V = portal vein. V H V = ventral hepatic vein.

I N T = intestine (mid-gut). S F = spiral fold.

FIG. 2.—Stage in metamorphosis—Stage 2. This, and all following stages, represent dorsal views. (9·5 cms. specimen). Lettering as in Fig. 1.

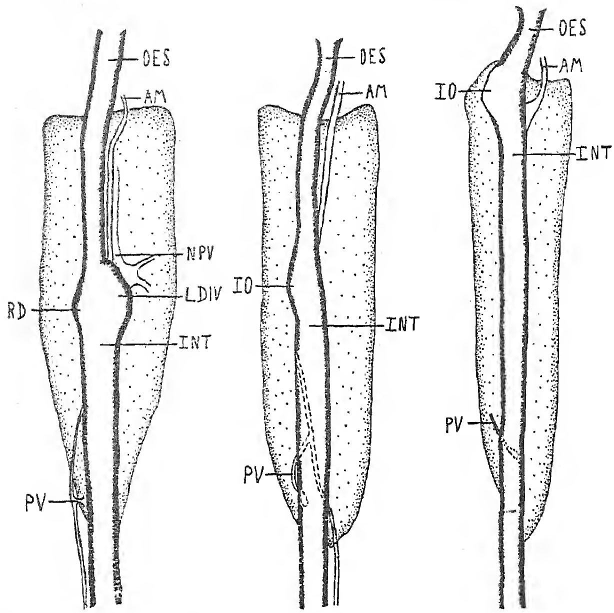


3 4 5

FIG. 3.—Stage 3. (10 cms. specimen). R.D. = swelling caused by remnant of right diverticulum and by islets of Langerhans budded from it. Lettering as in Fig. 1.

FIG. 4.—Stage 4. (10·1 cms. specimen). N P V = region in which new portal vein enters liver. Lettering as in Fig. 1.

FIG. 5.—Stage 5. (10·1 cms. specimen). Owing to the process of rotation the originally-left diverticulum (L.DIV) now lies on the right side. Lettering as in Fig. 1.



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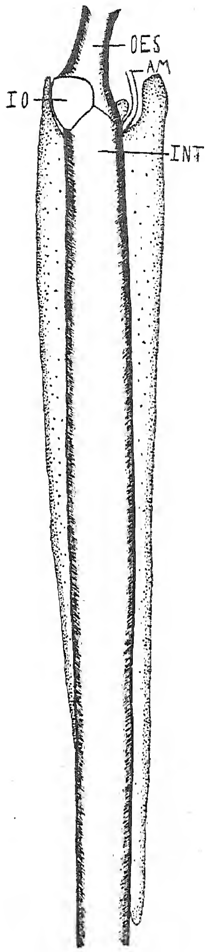

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FIG. 6.—Stage 6. (10·1 cms. specimen). Lettering as in Fig. 1.

FIG. 7.—Stage 7. (Specimen not measured). I O = insular organ. Lettering as in Fig. 1.

FIG. 8.—Stage 8. (9·8 cms. specimen). Lettering as in Fig. 1.

FIG. 9.—*Macrophthalmia* stage (completely metamorphosed *Ammocoetes*—9·3 cms. specimen). Lettering as in Fig. 1.

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Report on a Collection of Fresh-water Cyclopidae from New Zealand.

By FRIEDRICH KIEFER, Dilsberg (near Heidelberg).

[*Translated and communicated by E. W. Bennett; issued separately, 30th September, 1931.*]

THE more humble representatives of the fauna of the inland waters of New Zealand are as yet very imperfectly known. The various accounts yet published refer only to rather random samples; yet they are sufficient to show that (taking the Australian region as a whole) a highly distinctive character is given to the fauna of that region by a number of characteristic forms, such as, for example, those of the Copepoda. It is consequently a matter of considerable interest to systematists and no less to zoo-geographers to have some precise information concerning the fresh-water fauna of Australia and New Zealand and the various associated islands.

An extensive collection of New Zealand fresh-water animals from a variety of habitats has been sent to Professor V. Brehm by Mr E. W. Bennett, and, as shown in previous published reports, these collections have revealed quite a series of new and remarkable representatives of the lower Crustacea, particularly Copepoda of the subfamily Harpacticoida. Professor Brehm has entrusted the Cyclopids from these collections to me for investigation, and I wish to offer here my heartiest thanks for the opportunity of examining them.

The material received by me was contained in 34 tubes, whose contents were derived from the following localities:—

1. Waimate. Stagnant weedy pool.
2. Arno, S. of Waimate. Large flooded lagoon.
3, 4, 5. Timaru. Sluggish or stagnant pools, weedy.
6. Maronan Road, near Ashburton. Rapid turbid stream in flood.
7. Ashburton. Stagnant weedy pool on golf links.
8. Rakaia River bed, by railway bridge. Rapid stream, sandy bottom, without weeds.
9. Selwyn River bed. Very weedy pools, probably only rain-pools not flooded by the river.
12. Christchurch. Alga cultures in greenhouse, Canterbury College. Possibly originally from Arthur's Pass.
13. Selwyn Huts, mouth of Selwyn River.
16. Label lost. Canterbury.
17. Tai Tapu. Muddy ditch.
18, 20, 22. Governor's Bay, Lyttelton Harbour. Horse trough.
23. Brackish pool at Lake Ellesmere, connected with lake by a ditch.
24. Pool (? brackish) by Lake Forsaith, probably flooded by the lake in winter. The lake is brackish.

26. Arthur's Pass, summit, 2500 feet. Pool in alpine Sphagnum bog, water brown and curdy with flocculent decaying weed.
27. ? Arthur's Pass.
29. Sefton, North Canterbury. Shallow weedy stream, rather sluggish.
30. Sefton. Large deep pond, shaded by willows and covered with *Azolla* and *Lemna.*
31. Near Sefton. Rapid stream with few weeds.
32. Leithfield. Deep culvert, shaded by bridge; willows, and *Lemna.*
33. Greta Valley, North Canterbury. Very weedy pool, stagnant (? temporarily).
34. Gebbie's Valley, Banks Peninsula (Plains district). Shallow and muddy culvert.
35. Near Waipara River. Deep roadside pool.
36. Cheviot. Small muddy pool.
37. Cheviot. Sluggish stream, with *Lemna* and other weeds, and willows.
38. Near Hurunui River. Extremely turbid roadside pool.
39. Cheviot. Lake in the Park.
40. Cheviot. Lake in the Domain.
42. Nonoti, near Cheviot. Large weedy pond.
43. Lake Ellesmere. Brackish water.

In these 34 tubes, in spite of the variety of localities from which the material was taken, I could find only ten species of Cyclopidae, which were as follows.

1. *Cyclops bisetosus* Rehberg.
   ,, *bicuspidatus* Claus.
   ,, *monacanthus* Kiefer.
2. *Cyclops bicuspidatus* Claus.
   ,, *bisetosus* Rehberg.
3. *Cyclops bisetosus* Rehberg.
4. *Cyclops bicuspidatus* Claus.
5. *Cyclops bicuspidatus* Claus.
6. *Cyclops robustus* Sars.
7. *Cyclops robustus* Sars ? (badly preserved).
8. *Cyclops bicuspidatus* Claus.
9. *Eucyclops serrulatus* (Fischer) ?
   Cyclops robustus Sars ? (badly preserved).
12. *Paracyclops finitimus* Kiefer.
13. *Eucyclops serrulatus* (Fischer) ?
   Cyclops robustus Sars.
   ,, *monacanthus* Kiefer.
16. *Paracyclops finitimus* Kiefer.
17. *Eucyclops serrulatus* (Fischer).
   Cyclops robustus Sars.
18. *Cyclops robustus* Sars.
20. *Eucyclops serrulatus* (Fischer).
22. *Cyclops robustus* Sars or *Cyclops vernalis* Fischer (badly preserved).

23. *Cyclops monacanthus* Kiefer.
24. *Cyclops bicuspidatus* Claus.
26. *Macrocyclops albidus* (Jurine), 1 juv.
27. *Eucyclops serrulatus* (Fischer).
29. *Eucyclops serrulatus* (Fischer).
30. *Cyclops bicuspidatus* Claus.
31. *Eucyclops serrulatus* (Fischer).
32. *Cyclops robustus* Sars.
    ,, *bisetosus* Rehberg.
33. *Macrocyclops albidus* (Jurine).
    Eucyclops serrulatus (Fischer).
    Cyclops varicans Sars.
34. *Cyclops vernalis* Fischer.
35. *Cyclops bisetosus* Rehberg.
36. *Cyclops robustus* Sars.
37. *Eucyclops serrulatus* (Fischer).
    Paracyclops finitimus Kiefer.
    Cyclops robustus Sars.
    ,, *bisetosus* Rehberg.
38. *Eucyclops serrulatus* (Fischer).
    Cyclops bicuspidatus Claus.
39. *Eucyclops serrulatus* (Fischer).
    Cyclops robustus Sars.
40. *Cyclops bicuspidatus* Claus.
42. *Cyclops bicuspidatus* Claus.
43. *Cyclops crassicaudoides* Kiefer.
    ,, *monacanthus* Kiefer.
    Eucyclops serrulatus (Fischer) ?

The systematic arrangement of these species is as follows:—

Genus **Macrocyclops** Claus.

Macrocyclops albidus (Jurine).

Genus **Eucyclops** Claus.

Eucyclops serrulatus (Fischer).

Genus **Paracyclops** Claus.

Paracyclops finitimus Kiefer.

Genus **Cyclops** O. F. Müller.

Cyclops (Acanthocyclops) robustus Sars.
,, (,,) *vernalis* Fischer.
,, *(Diacyclops) bicuspidatus* Claus.
,, (,,) *bisetosus* Rehberg.
,, (,,) *crassicaudoides* Kiefer.
,, *(Microcyclops) varicans* Sars.
,, *(Metacyclops) monacanthus* Kiefer.

This list can be regarded as only a scanty one, and I am convinced that twice as many species of Cyclopids occur in the district in question. There are several reasons why they may well have escaped record here. First, anyone wishing to include Cyclopids in his collections of the fresh-water fauna must be familiar with the habits

of these animals, and the habits differ considerably in the species of the various groups. It is remarkable, for example, that in none of the tubes is there a single truly planktonic species, such as a member of the genus *Mesocyclops;* or that of the creeping rather than free-swimming forms, the *serrulatus* group of the genus *Eucyclops* is represented by only a single species, and the genus *Ectocyclops* is not represented at all. It is obvious, moreover, that not all of the species occurring in a given locality can be collected by a single visit to that locality, for the collecting should be spread over a considerable time, say a year at least, in order that those species may be collected which are absent or only very sparingly represented at some seasons. Finally, another important factor is the thoroughness or otherwise of the subsequent examination of the material, and, in the present case in particular, the picking out of the Cyclopids from the original bulk catch; for one whose aim is the study of animals of all descriptions may easily pass over a number of small or otherwise inconspicuous species which a specialist would most probably detect.

We may therefore conclude that since only ten authentic forms of free-living fresh-water Cyclopids are known from the whole Dominion of New Zealand, and since on a rough estimate this can be only about one-third of the total number of species which may confidently be expected to occur there, our knowledge of the New Zealand Cyclopids is still highly incomplete, and there is a wide field for investigation by local zoologists.

The further geographical distribution of the New Zealand Cyclopids, so far as they are known, is worthy of note. Seven species (*Macrocyclops albidus, Eucyclops serrulatus, Cyclops robustus, C. vernalis, C. bicuspidatus, C. bisetosus*, and *C. varicans*) are very widely distributed, and their occurrence in New Zealand calls for no further comment. The remaining three species, however, serve to give a distinctive character to the New Zealand Cyclopid fauna. One of them, *Paracyclops finitimus*, is at present known, apart from the New Zealand record, from North and South Africa. *Cyclops crassicaudoides* and *C. monacanthus* appear to be endemic to New Zealand, but they do not present any very remarkable features and are closely related to species with a wider distribution; viz., *C. crassicaudoides* is related to *C. bisetosus* (which itself occurs in New Zealand) and to *C. crassicaudis*, while *C. monacanthus* is related to *C. minutus* and *C. arnaudi*.

The only works, so far as I know, which have previously dealt with the New Zealand Cyclopids are from the pen of the Hon. G. M. Thomson, whose earlier paper, however, I have been unable to consult. I cannot express a personal opinion, therefore, on the species there described as new under the name of *Cyclops novaezealandiae*, but Schmeil has concluded, after studying certain specimens which were sent to him, that this species is not separable from "*Cyclops serrulatus.*" But since the latter species has since been dismembered into a whole series of independent forms, we can hardly state in precise modern terms what Schmeil's opinion amounts to. Schmeil also united *Cyclops gigas* Thomson with *Cyclops bicuspidatus* Claus,

but although I have concurred with this view in my account of the Cyclopidae in the "Tierreich," I now find a difficulty in so doing, in that Thomson was able to distinguish his form from *Cyclops bisetosus*. According to Schmeil, *Cyclops chiltoni* is a synonym of *Cyclops fimbriatus*, but the form of the furca as figured by Thomson did not, in my opinion, permit an easy identification with that species, but placed it much nearer to *forma inominata*. But now that I have identified the material of *Paracyclops* before me as *P. finitimus*, the possibility remains that Thomson likewise had this form. I believe that *C. chiltoni*, therefore, cannot in any case be now regarded as a valid species. Finally, in my account in the "Tierreich," I have expressed the opinion that *Cyclops aequoreus*, on account of the shortness of the furca, is possibly identical with *Halicyclops propinquus* Sars.

If the above brief discussion of the first large collection of fresh-water Cyclopidae from New Zealand leads to a more detailed investigation by local zoologists and fresh-water biologists, the aim of this paper will have been thoroughly attained.

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The New Zealand Species of Gigartina.
Part II (Foliose Forms).

By Robert M. Laing, B.Sc., F.N.Z.Inst.; and H. W. Gourlay, M.Sc.

[Read before the Philosophical Institute of Canterbury, 4th June, 1930; issued separately, 30th September, 1931.]

Part I of this paper dealt with the narrower non-foliose forms of Gigartina. We are now concerned with what may be termed the foliose forms. Practically all the species here considered produce foliar expansions 5 cm. or more in width. They fall into different divisions of Agardh's classification; but chiefly appear subsequent to those already described in our earlier paper. They present similar difficulties to the non-foliose forms in an accentuated form. Some of them are extremely polymorphic, and not only this, colour and texture which have been used by Agardh to some extent for specific characters, alter largely with the age and environment of the specimens. Thus **Gigartina atropurpurea** is often in parts red, maroon, brown, yellowish, almost black, and at times purple when held up to the light. Its texture, too, varies much with age. Young fronds are thin, bases of fronds cartilaginous; but in old age many of the fronds which had been thick and coriaceous again become thin and membranous, apparently owing to the collapse of the interior cells. No doubt, also, the varying methods of preparation will contribute to varying colours and textures of the frond. Hence such characters as colour and texture can only be used with great discrimination in the determination of species. Another character apt to be misleading is the margin of the frond, which may vary much in different parts of one plant; but still is frequently useful for the separation of one species from another when carefully used. The further difficulties of classification will appear when we consider the individual species.

We have first to thank sincerely Dr H. Kylin, of Lund, for photographs of Agardh's type specimens. These have been of great assistance to us.

Division C.

With the frond on one side more or less channelled or concave, on the other angular or convex, sometimes teretely stipitate below, the upper part more or less expanded, the position of the cystocarps varying with the mode of branching.

(Tribe I was dealt with in the first part of the paper).

Tribe II.—*Stipitatae*: Frond above the somewhat terete base more or less expanded into cuneate segments bearing the cystocarps on the concave side.

One species of this Tribe (**G. tuberculosa**) has already been dealt with in the first part of this paper. The following still remain for consideration (Agardh 1899 p. 28 et seq.).

G. radula (Esp.) J. Ag. (*Species excludenda*).

19. **G. lanceata** J. Ag. (1899), p. 29.

G. fissa (Suhr.) J. Ag. (1876), p. 201. (*Species excludenda*).

20. **G. atropurpurea** J. Ag. (1885), p. 31.

(It should be pointed out that the forms included by Agardh in his Division C are very diverse. **G. alveata** and **G. ancistroclada** are very far removed from such species as **G. radula** and **G. atropurpurea** and should not be included with them. Until, however, we have a monograph on the genus, Agardh's classification must to a large extent be adopted. The principal character relied on by Agardh in grouping such heterogeneous forms together is the concavity of the stipe or of some portion of the frond: but in some cases at least this characteristic is scarcely observable).

Division D.

Frond flat, sometimes almost without a stipe, sometimes with a more or less evident stipe and a terminal lamina, simple or variously subdivided. Cystocarps produced from the unaltered frond and more or less covering it, or confined to certain parts of the frond, or in minute leaves produced from the surface of the frond.

Tribe I.—*Apodae*: Immediately expanded above the radial disc into an orbitose frond more or less reniform, and sometimes cut into laciniae of indefinite shape. Hemispherical cystocarps chiefly on one side of the frond.

21. **G. apoda** J. Ag. (1899), p. 31.

Tribe II.—*Homaeopodae*: Frond flat, sub-dichotomously decompound with a sublinear stipe gradually passing into laciniae cuneately expanded, papillate on both sides and margins, the papillae producing gigartinoid cystocarps in immense numbers.

G. grandifida J. Ag. (1876), p. 176. (*Species delenda*).

G. rubens J. Ag. (1899), p. 34. (*Species inquirenda*).

Tribe III.—*Brachypodae*: Stipe very short, putting forth a frond often with others undeveloped from a radical disc, expanded into a broad blade, sometimes orbicular. Margins often toothed, at length, except in the marginal region, producing unarmed gigartinoid cystocarps.

22. **G. circumcincta** J. Ag. (1876), p. 202.

G. orbitosa J. Ag. (1899), p. 36. (*Species excludenda*).

Tribe IV.—*Heteropodae*: Frond with undeveloped laminae at the base, expanded above the stipe into laminae of very varied shape, linear lanceolate, oblong, cuneately dilated or even very broad, putting forth papillae often lingulate at first, at length gigartinoid, covering the whole lamina except the marginal region.

23. **G. longifolia** J. Ag. (1899), p. 36.

DESCRIPTION OF SPECIES.

Division C.

Tribe II.—*Stipitatae.*

Gigartina radula (Esp.) J. Ag. *Species excludenda.*

G. radula was the first species of **Gigartina** to be listed from New Zealand. It appears in Bory (1829), "Voyage de la Coquille," under the name *Iridea radula*, and again is recorded under the same name in Hook. and Harv. 1844, p. 76. In Hook. 1876, p. 700, and in Laing (1909), p. 506, "Marine Algae of the Sub-Antarctic Islands of New Zealand." Indeed, for about one hundred years, it has been regarded as a native of New Zealand, yet it probably does not occur here.

In the first place it is evidently a composite species in which is included a number of distinct forms, and all the apparent forms of *G. radula* from New Zealand seem now to have been sorted out by J. Agardh into other species. Unfortunately, we have not had access to Harvey's specimens, and so are unable to say how they should be classified; but it is quite clear that most of the forms hitherto classified under *G. radula* for New Zealand will have to be placed in **G. circumcincta.** One specimen that the senior author had long in his herbarium under the name *G. radula* var. *amethystina* is now seen to be only a fragmentary specimen of **G. atropurpurea.** Other plants once believed to be *G. radula* have had to be placed under **G. lanceata**; and we have now no specimens from New Zealand that we can regard as authentic *G. radula.* **G. circumcincta** is readily distinguished from *G. radula* by its sterile intra-marginal belt and by the absence of lingulate laminal processes; **G. atropurpurea** has a much more developed system of branching than *G. radula* and has proliferous leaflets on the margin of the main lamina, whereas the frond of *G. radula* is usually simple. **G. lanceata** may usually be readily distinguished from *G. radula* by the presence of the hooked marginal processes along the margins of frond in the former and their absence in the latter. It has also much narrower, more cartilaginous fronds, darker in colour than those of *G. radula.*

We have seen several specimens of authentic **G. radula** from South Africa. One is Agardh's variety **hystrix** (*Mastocarpus bracteatus* Kuetz.), and we have certainly seen no specimen in New Zealand matching this form. Another is sterile and might possibly be matched with New Zealand specimens; but these latter develop differently from **G. radula.** J. Agardh (1877), p. 16 No. 136, under **G. circumcincta** has the following note, "*Gigartina radula* Harv. Fl. Nov. Zeland, non Esp. et alior.," nor does he insert **G. radula** in this list. We must therefore conclude that he rejects it as a New Zealand species; and we must do the same until better evidence of its presence in New Zealand is forthcoming.

The plants identified as *G. radula* by the senior author in "Marine Algae of the Sub-Antarctic Islands of New Zealand" are in a poor state of preservation, but some of them are certainly **G. circumcincta** and the others probably so.

19. **Gigartina lanceata** J. Ag. (1899), p. 29. *G. fissa* J. Ag.; *G. grandifida partim* J. Ag. (Pl. 16: Figs. 1-6).

This species was described by Agardh from specimens sent by Baron von Mueller from the West Coast of New Zealand, collected by Captain Fairchild, of the Hinemoa. We have only seen photographs of Agardh's original specimens, but we have forms which agree well with the description. It reaches 60 cm. at least in length and is usually not more than 5 cm. wide. It is generally to be recognised by the hooked, curved, appressed, or bent processes lining the margin, covering the lamina and turned towards the apex. Cystocarpic and tetrasporic forms are similar in shape. The plant is usually blackish when dried but reddish and translucent when fresh. **G. lanceata** is placed in the tribe *Stipitatae* by Agardh ("frondibus supra stipitem ima basi teretiusculum, mox plus minus canaliculatum") (1899) p. 22; but he says in his diagnosis of the species loc. cit. p. 28: "Frondibus, ima basi vix conspicue canaliculatis," so that this character scarcely becomes significant. The thickened margin girding the frond is another character mentioned by him which is not always observable. We consider this species would be better placed under the Tribe Homaeopodae with flat fronds.

G. lanceata: Fronds tufted, stipe terete at the base for several mm. or more, then usually becoming grooved and linear for a cm. or two, when it passes into the sub-cuneate base of the frond. The stipe is sometimes provided with one or two ligular folioles, but these are often absent. Frond linear lanceolate to lanceolate, 40 cm. to 60 cm. long, 4 cm. to 10 cm. broad, thin and membranous when young, but becoming extremely thick and coriaceous when mature, often undivided, but sometimes forked or variously and sparsely branched. Both surfaces and margin usually become covered with terete, linear or club shaped processes up to 5 mm. in length but generally shorter, bent towards the apex. In luxuriant cystocarpic specimens, these bristles are irregularly branched and form a mat covering the surface of the frond completely. Sometimes they develop into linear-lanceolate folioles. They are wanting from the young growing tips, but are usually present in both cystocarpic and tetrasporic forms. The cystocarps are usually developed at the apex of the processes on the surfaces and margin of the frond: but sometimes below the apex. They sometimes, however, appear in the first place as papillose swellings, and then develop a stipe, curving towards the apex of the frond. In mature plants, the fertile processes are often irregularly branched and bear several cystocarps. The largest ones are to be found on the margins and round perforations in the frond, and are copiously branched. In some states the plant closely resembles a specimen of the Californian **G. radula** f. **exasperata** sent to us by Dr W. A. Setchell (Californian Algae No. 2049). Indeed, the two may not be specifically distinct, though without further Californian material, it would perhaps not be safe to assimilate them.

Tetrasporic forms are quite similar to the cystocarpic; but bear fewer and shorter processes. These are sterile and do not exceed a millimetre or two in length. Fertile specimens September to May.

In Laing (1926) p. 151, this species is erroneously recorded as being found in Australia. So far it is only known from the South Island of New Zealand.

St. Clair, J. Crosby Smith; Moeraki Lighthouse, Double Corner (Amberley), Gore Bay, R.M.L.; Kaikoura (drift), H.W.G.

Gigartina fissa Suhr. 1836 I. p. 24. (*Species excludenda*).

We have little doubt that the plant so identified for New Zealand by Agardh is merely a form of **G. lanceata** J. Ag. **G. lanceata** is No. 50 and *G. fissa* is No. 51 in his group *Mamillosae*, J. Ag. 1899, p. 28, 29. The following are his diagnoses of the two species:—

> **G. lanceata** J. Ag.: "Frondibus ab expansione radicale subscutata in caespitem foliorum fere immediate exeuntibus, ima basi vix conspicue canaliculatis, mox in laminam lineari lanceolatam, margine incrassato cinctam abeuntibus, cystocarpiifera fronde intra marginem serratum in utraque pagina papillas plurimas, sine conspicue ordine dispositas generante, sorifera fronde consimili sphaerosporas intra frondem immersas generante."

> *G. fissa* Suhr.: "Frondibus in stipite sublineari cuneato, ipso in lacinias paucas canaliculatas, frondem (quoque juniorem sustinentibus subdiviso, segmentis in frondem cuneato-obovatam excrescentibus, demum quoque a margine foliola nova canaliculato-plana generantibus; cystocarpiiferis tum a margine, tum ab utraque pagine papillis gigartinoideis uberrime instructis."

(1) The first point to be noticed in these descriptions is the differences given for the bases. In **G. lanceata** the base passes almost immediately into the frond, in *G. fissa* it is sub-linear cuneate. Now we have photographs of Agardh's types, and there is no such clear distinction in the form of the base as represented in the description. In all cases where the base is clearly shown, it is as in the description as already given by us.

(2) The next point is that in *G. fissa* immediately above the base the frond is divided, whilst in **G. lanceata** it passes into an undivided lamina. Now some of the photographs of Agardh's *G. fissa* certainly show this characteristic; but so also does one of the specimens of **G. lanceata.** Species of **Gigartina** show so much polymorphy in form of frond that no weight can be placed on a character like this in establishing a distinction. **G. lanceata** is no exception in this respect; the frond is generally undivided and linear lanceolate; but is at other times as might be expected divided in a great variety of ways. This division is no doubt due to epharmonic modifications or to the direct action of wind, waves, and rocks.

(3) The third point of difference is that **G. lanceata** is without marginal folioles, whereas they are stated to be present in *G. fissa.* Amongst our specimens, there are some which bear all the other characteristics of **G. lanceata,** but have marginal folioles such as

appear in Agardh's *G. fissa.* We cannot consider this character alone sufficient to distinguish a new species; nor do there appear to be any other characters of value distinguishing the two forms. Hence it may be concluded that *G. fissa* J. Ag. is merely a form of

G. lanceata J. Ag.

The next matter for consideration is whether **G. lanceata** J. Ag. may be *G. fissa* Suhr. (1836) I. p. 24.

The original description of Suhr is not available to us. The plant was first collected at Cape Horn, and Agardh had only a miserable example of it. Agardh doubtfully identifies it with *Iridaea lanceolata* of Harvey (1876, p. 201). However, *I. lanceolata* Hook. f. et Harv. (1867, p. 701) is stated to be 1 to 2 feet long, red purple, crisped and waved, 1 to 3 inches broad, lanceolate, tapering at both ends. This is obviously a different plant from **G. lanceata.** Nor does **G. lanceata** appear to be the original *G. fissa* of Suhr. Tetrasporic plants were collected by Hariot at Cape Horn (Hariot 1882-83, p. 69); but he adds nothing of value to Agardh's description. The plant is evidently close to **G. radula;** and it would be quite unsafe to identify it with **G. lanceata.** Agardh's specimens of *G. fissa* came from the Bluff. Unfortunately we have no specimens of **G. lanceata** from there; but there can be no hesitation in at present excluding *G. fissa* from our catalogue of New Zealand plants.

20. **Gigartina atropurpurea** J. Ag. (Pl. 17).

This species was first described by J. Agardh (1876), p. 181, under the name *Iridaea atropurpurea.* It was collected by Berggren at the Bay of Islands, and again appears in J. Ag. (1877), p. 15, as *I. atropurpurea.* However, in (1885) p. 31, Agardh in the meantime having obtained cystocarpic specimens which before had been wanting, transferred the plant to the genus **Gigartina,** giving some additional descriptive details.

It is an abundant species, particularly in the neighbourhood of Lyall Bay; and one which when fully developed is readily identified by the form of the frond. Fragments, however, are often difficult to separate from adjacent species. We have seen photographs of the type and have little doubt as to the accuracy of our determination. However, the colour and texture vary much with age and environment of the plant. Young plants are often rose-pink in colour and almost membranous, whilst old ones may be cartilaginous and dark brown to black. When the surface cells are worn off it becomes olive yellow to green. The name **atropurpurea** is therefore somewhat misleading, as it is only occasionally that it is of this tint.

G. atropurpurea J. Ag. The disc gives rise to a short terete stipe 4 mm. to 5 mm. in length, sometimes much shorter. This usually flattens out into a short, cartilaginous, subcuneate stem, generally 5 cm. to 10 cm. in length from the sides and outer ends of which are developed fronds on secondary petioles which again subdivide and produce pinnae of varying and irregular shape. In a few cases a large sub-cordate frond is developed directly from

the primary stipe. In such cases the plant simulates **G. circumcincta;** but is usually to be distinguished by the absence of the sterile intra-marginal area. The primary stem may vary in shape from oblong to narrow linear, and in some cases is even broader than long. The fronds, too, are polymorphic in form, linear when young, developing to linear lanceolate, oblong, elliptical, or more rarely rotund. The narrower forms are more numerous. Individual fronds are often irregularly torn and divided. Young growths are almost membranous and pale in colour. Mature fronds are deep brown almost black, thick and cartilaginous. Old fronds are thinner, often much perforated, and red brown. In the young state the margin is entire and usually remains so in tetrasporic specimens; at other times it becomes irregularly dentate or ligulate, the ligules growing into new laminae. Decaying fronds are frequently covered on the lamina and margins with more or less triangular papillae bent towards the apex. The total length of the plant is 30 cm. to 40 cm., and not usually more. The total breadth may be 20 cm. to 30 cm.

Particularly when the original lamina has been injured, there is a tendency to develop in irregular succession fresh pinnae from the margins of the old frond. These pinnae form a rounded stipe, develop a subcuneate petiole, and are frequently to be found in such cases on the uninjured as well as on the injured edge of the frond.

Cystocarps are developed on both sides and margins of the frond. They are small (·3 mm. to ·5 mm. in diameter in dried specimens) sub-sessile and usually solitary; though occasionally, particularly on the margin, provided with a short stipe.

Tetrasporic plants are similar to cystocarpic and produce sporangia in large numbers scattered below the surface of the frond.

G. atropurpurea is usually found in rocky tidal channels on the open coast.

Akaroa, New Brighton (drift), Double Corner (Amberley), Gore Bay, R.M.L.; Wellington Heads, R.M.L. and H.W.G.; Muriwai (Auckland), M. C. Crookes; Bay of Islands, Berggren; Anawhata, L. M. Cranwell.

DIVISION D.

Tribe I—*Apodae.*

21. **Gigartina apoda** J. Ag. (Pl. 18: Figs. 7-10).

G. apoda (1899), p. 31, is the only species placed by Agardh in this tribe. We believe that we have satisfactorily identified it; but Agardh was obviously working with an incomplete range of specimens; and it is a plant which varies greatly with the season of the year and the age of the fronds. His description is therefore incomplete and at times misleading. Agardh states (loc. cit.) that amongst the New Zealand species in his herbarium, he had long had one which he placed beside **Aeodes** because of its similar habit; but when he had obtained a fruiting specimen found that it should be placed in **Gigartina.** Further, he considers that it is an aberrant

form of **Gigartina** for reasons given that we shall presently consider. Now from Agardh's description it would appear that he had chiefly young specimens to deal with. True, the photographs of the type show certain fragments of old fronds; but evidently Agardh had not enough specimens of these and of the winter form to be able to form an adequate idea of their characters. We shall now discuss the questions raised by him. (1) We cannot find anything in his description of the microscopic structure of the frond to indicate that it should not be placed in the genus **Gigartina.** He refers to certain "maculas rotundas" in his sections. These are probably only cross sections of the strands. We have made a number of sections of juvenile, mature, and old fronds, and though in some cases the anastomosing threads are shrunken and in others stuffed with cell contents, we can find nothing in the structure that is not typical of **Gigartina.** The structure is of course quite different from that of **Aeodes.** (2) The tribe is founded on the supposed *apod* nature of the frond: "frondibus supra scutellum radicale immediate expansis." While it is quite true that this is the case in young fronds superficially resembling **Aeodes,** this is not the case in mature fronds in which the stipe is as well developed as in **G. circumcincta.** In mature tetrasporic forms, the stipe often passes into a sub-cuneate base and in cystocarpic fronds it is often branched, each branch giving rise to an undivided frond. Divided fronds are rare, though it is occasionally possible to find one which is cleft. Stipes 1 cm. to 2 cm. in length are not uncommon, occasionally channelled (perhaps as a result of drying) and bearing several undeveloped leaflets. It will therefore be seen that no good characters can be founded on the form of the stipe in the mature plant, though certainly the juvenile form of it appears characteristic. Only those who have watched the plant through all seasons of the year would associate together all the forms included in the species. It is not therefore to be wondered at that Agardh, who had not seen the plant growing, should be unable to give a complete description of it. We have collected scores of specimens at various seasons from the back of the Gladstone Pier, Lyttelton, obviously of the one species, and a few from other localities. We should certainly have regarded the forms as belonging to different species if we had seen only a few specimens. (3) Agardh further remarks in his notes: "Attamen cystocarpia tantum in una pagina, provenientia mihi adparuerunt, ex qua adparentia forsan esse decumbentem, et poros, quos juniores vidi tantum caecos et in una pagina fructiferos aperta, margine vero recurvato hujus pagina cinctos, demum grandescentes et frondem rite pertusam linquentes-haec omnia speciem vario respectu ab aliis Gigartinis diversam indicare, non potui quin monerem." We find it difficult to understand these remarks. (a) The cystocarps confined to one side of the frond. This is not an uncommon characteristic with certain species of Gigartina; but it is a character which again has to be used with discretion. In **G. atropurpurea** the cystocarps are sometimes fairly equally distributed on both sides of the frond; but often specimens may be found in which the distribution is quite unequal. In other species, specimens may be found in

which not a single cystocarp is to be found on the lower side of the frond, though the other side is closely covered with them; or again, in the same species, parts of each side of the frond may be cystocarpic, but these parts are not so opposite to each other, the plant being unable to produce cystocarps at the same time on different sides immediately opposite to each other. If produced, they would probably result in the destruction of that portion of the frond owing to the number of pores left by the fallen or decayed cystocarps. (b) Most of the foliose **Gigartinas** have perforated fronds when old, owing to the decay of the cystocarps. Probably Agardh had not come across such specimens. This is particularly the case with **G. atropurpurea** and **G. circumcincta.** We can see no reason for regarding the plant as in any way an aberrant species of **Gigartina.**

Gigartina apoda J. Ag. (1) In the juvenile condition of **G. apoda** found chiefly in winter and spring, the stipe is only a millimetre or two in length and develops usually into a more or less orbicular undivided frond. The margin is at first entire but later dentate or irregularly serrate. The stipe is often naked but may bear one or more ligulate undeveloped fronds. The mature frond when dried may be as much as 40 cm. to 50 cm. across; but is usually smaller (15 cm. to 25 cm.), thin, in younger stages almost membranous and often rose-red. Though typically orbicular, it is sometimes elliptical or even ovate, flat or at other times cochleate with a thickened rim round the margin. (2) The mature cystocarpic form is found at all seasons of the year, except perhaps in early spring, when however, old decaying perforate cystocarpic fronds are not uncommon. The chief characteristics are (1) the narrow sterile intra-marginal band; (2) the cystocarps never appearing simultaneously on exactly opposite parts of the frond, and often confined more or less to one side only; (3) the pitted surface below the cystocarps; (4) the cystocarps solitary at first, but becoming bunched, fascicled, or borne on irregularly branched peduncles as the season advances; and finally (5) the usually orbicular or very broadly expanded form of the frond. The cystocarps are of the usual type, generally from 1 mm. to 1·5 mm. in diameter in dried specimens. In old fronds there is a cystocarpic fringe round the margins. The colour of the mature fronds is usually a fairly uniform dark brown when dry. Younger dried fronds are much lighter in colour, and often have a yellowish or greenish yellow tinge. Tetrasporic plants are much less abundant than cystocarpic, and do not show any definite intra-marginal sterile band. The few we have were collected in April, and are not sufficient in number to generalise upon. They show a definite tendency to the development of a subcuneate base, not present in the cystocarpic form. The margin is entire, becoming later coarsely toothed or even somewhat foliolate.

Mason Bay (Stewart Island) one slightly doubtful specimen; Timaru (North Mole), Lyttelton (Gladstone Pier, abundant), New Brighton (drift), Gore Bay, Breaker Bay (Wellington), R.M.L.; the Chathams (? Collector).

Tribe II.—*Homaeopodae.*

Gigartina grandifida J. Ag. *Species excludenda.*

This appears to us to be, in part at least, only one of the forms of **G. lanceata** J. Ag. We have a photograph of the type specimen and a single additional specimen. The plant was apparently described from specimens collected by Travers at the Chathams. The description appears in J. Agardh 1876 (pp. 199 and 200). It is quite evident that here again the author had an insufficiency of material, and so was unable to recognise the wide range of forms that may occur in a single species. The photograph shows **G. lanceata** split above the base into two widely divaricating fronds of the usual type, cystocarpic, and bearing along the margin at least the usual bent processes. Now though we do not happen to have any specimens of **G. lanceata** exactly matching these—and it is difficult to find two specimens exactly alike—yet we have several with widely divaricating branches some distance above the base, and we cannot see in this inconstant character any reason for separating out a fresh species, *G. grandifida.*

But **G. lanceata** and *G. grandifida* are placed by Agardh not only in different tribes, but in different sections of the genus. To us it would appear that they are so closely allied as to be collateral species at least, if not actually the same. **G. lanceata** is classified with **G. stiriata, G. radula,** and **G. Burmanni** because it sometimes has a channelled stipe. Yet though it is true that sometimes in dried specimens particularly, the stipe of **G. lanceata** is channelled, the character is obviously here valueless for the purpose of determination. This being so, there is no reason why *G. grandifida* and **G. lanceata** should be placed in different sections of the genus, because of alleged differences in this respect. In *G. grandifida* the stipe is stated to be flattened, not channelled. Such points are of course difficult to make out from a photograph, but to us the photographs of both species seem to show an equal amount of channelling of the stipe. The only other distinction that we can find between them in the descriptions of the species has already been alluded to. In *G. grandifida* the lamina is said to be bifid, simple, or forked; in **G. lanceata** it is linear lanceolate. We have seen hundreds of plants of **G. lanceata,** and amongst these are a few which correspond with Agardh's description of *G. grandifida,* but we do not regard these as being sufficiently numerous or distinctive to constitute a good species; and we therefore propose that *G. grandifida* be excluded from the list of the species of **Gigartina.**

It is also probable that certain forms of **G. circumcincta** and **G. atropurpurea** are included in Agardh's *G. grandifida.* In J. Agardh 1885, p. 50, it is stated of this species, "Plurimis affinibus tenuior et colore plerumque dilute rosea aut pallido plantae exsiccatae diagnoscenda." As we have already pointed out, colour and texture must be used with discrimination in the determination of a species. There is in the Otago Museum a fragment of *G. grandifida* identified by Agardh; but it is sterile and quite insufficient to provide means of definite determination. It has the pale rose colour and thin

texture insisted upon in Agardh's description, and exactly matches certain plants of **G. atropurpurea** collected by the senior author at Akaroa.

Further, the photograph of the type that we have seen is scarcely sufficiently definite to show the texture of the plant photographed. If thin, the type specimen might probably be a form of **G. circumcincta.** We come therefore to the conclusion that *G. grandifida* as a species probably does not exist; but that the group as defined by Agardh probably includes forms of **G. lanceata** and possibly also of **G. circumcincta** and **G. atropurpurea.**

Gigartina rubens J. Ag.

Agardh in 1876, p. 685, described two varieties of *G. grandifida.* The second of these, var. b. *latifolia* he subsequently (1885), p. 31, distinguished with the specific name of *rubens,* describing it in (1899) p. 34. The specimens are from the west coast of New Zealand, doubtless collected by Captain Fairchild and presented to Agardh by Baron F. von Mueller. There is little or nothing in the appearance of the photographs of the type to distinguish it from **G. circumcincta** except possibly the cordate base. Specimens of **G. circumcincta** with a cordate base are, however, not lacking. Why Agardh should in the first place have associated this plant with *G. grandifida* is not clear. Indeed, he himself says (loc. cit.), p. 34: "Ejusmodi formae et ramificationis differentias, quibus omnes ad species dignoscendas conatus—si quidem characteribus ex frondis forma et ramificationis norma petitis insisterent—repulsos fere diceres, non potui quin stupens adverterem." Now the characters given in the diagnosis are a cordate base, passing into an ovate, reniform frond, branching into two or three forks, with lobes growing sub-pinnately (from the margins). Yet the photograph of the type does not show any sub-pinnate lobes, and of the three fronds shown, two are once divided and the other is practically undivided. However, the fronds in the photographs do not show an intra-marginal sterile band under a lens, and so the plant would seem to differ from **G. circumcincta,** though it is questionable how much stress should be laid on this peculiarity. We have certain non-circumcinct specimens found growing on empty shells at Purau (Lyttelton) which seem to match well with Agardh's description, and fairly well with his photographs, but as they are few in number and the form has not again been collected, we hesitate to identify them definitely with **G. rubens.** The species must therefore be left in our list of *species inquirendae.*

Agardh's diagnosis is as follows:—" Stipite brevi juvenili aut fere immediate in laminam 2-3 furcam abeunte, aut evolutione tum laminae a cordata basi in folium ovato reniforme abeuntis, tum lobis excrescentibus frondem subpinnatim decompositam gerentibus."

Tribe III.—*Brachypodae.*

These species are characterised by a short petiole surmounted usually by a broad, little divided frond, lanceolate to orbicular. On the short petiole there are generally several small undeveloped

fronds. They are further characterised in the cystocarpic specimens at least by a sterile inter-marginal band. Cystocarps are developed more or less evenly on both sides of the frond or confined to different parts of opposite sides. Agardh recognises three species, **G. circumcincta**, *G. orbitosa*, and *G. gigantea*. Of these, **G. circumcincta** is an abundant well defined species. *G. orbitosa* is separated from **G. circumcincta** chiefly by the form of the frond, the size, the more cartilaginous texture, and the colour tending to purple. Now none of these characters is distinctive, and we propose to include *G. orbitosa* with **G. circumcincta.** Indeed, we cannot separate it even as a variety. We have a large series of forms of **G. circumcincta** collected between Timaru and Wellington; and these include specimens which match the photograph of the type specimen of *G. orbitosa*, yet they all apparently belong to one species. Agardh originally included his specimens of *G. orbitosa* with **G. circumcincta,** and only made the separation in his latest writings. We have further the photograph of the type specimen of *G. gigantea*, labelled "Banks Peninsula, New Zealand, Berggren." Now Agardh (1899), p. 37, does not record *G. gigantea* from New Zealand, but from Tasmania and Australia, apparently overlooking the fact that his type was from Banks Peninsula. The character which chiefly separates *G. gigantea* from **G. circumcincta** is the development of marginal folioles and laciniae. **G. circumcincta** is usually entire or only once or twice divided. We have, however, several such **Gigartinas** with marginal folioles and laciniae, such as are represented in the photograph of the type of *G. gigantea*. These specimens were found at Lyall Bay and Kaikoura, in company with undoubted specimens of **G. circumcincta,** and we cannot believe that they represent a separate species, but only such modifications of the form of **G. circumcincta** as may well be expected in such a polymorphic genus. If the name *G. gigantea* is retained at all, it should only be as a form of **G. circumcincta.** We have also a small fragment—insufficient for identification—of a **Gigartina** 18 inches across, from Eagle Hawk Neck, Tasmania. This was given us by Mr A. H. S. Lucas, and by him labelled *G. gigantea*, but though cystocarpic, there is insufficient material for a satisfactory comparison with New Zealand forms.

22. **Gigartina circumcincta** J. Ag. (Pl. 19: Figs. 11-12).

This species was founded by J. Agardh (1876), p. 202, to replace the *G. radula* from New Zealand of other authors. We have already considered their relationships under *G. radula* (sp. excl.), and the general characters of **G. circumcincta** have just been given under the section *Brachypodae*. It now remains to consider them in somewhat more detail. As in other forms, a considerable amount of polymorphy is shown, but the species is usually recognisable. It grows (at Kaikoura) up to 1 metre in length and 20 cm. in breadth. From the scutellum it usually passes at once into a short, terete stipe which may be only 2 or 3 millimetres in length, then into a short cuneate base which expands into the frond. The stipe usually carries several ligular expansions; these

however in some cases are developed into folioles. At times too, the stipe is almost wanting and the frond expands immediately above the scutellum; or again the terete petiole may be several centimetres in length; but the base is rarely if ever so well developed as in **G. atropurpurea** or **G. lanceata.** The frond is typically lanceolate to ovate or elliptical, more rarely rotundate, usually narrowed and rounded towards the apex. It is frequently undivided, but sometimes forked. The margin may be irregularly toothed, lobed, or entire. Processes such as are characteristic of **G. lanceata** and **G. radula** are usually wanting. We have, however, several old specimens having linear processes on the surfaces and margin, 3 mm. to 5 mm. long, with cystocarps at the apices. The cystocarps are, however, solitary normally sub-sessile, sometimes abundant on both sides of the frond, but more often in patches with a sterile area immediately opposite on the other side. The sterile marginal band is usually only 2 mm. to 3 mm. in width and is sometimes lacking in old and worn fronds. Cystocarps up to 1 mm. in diameter are produced in immense numbers without terminal or lateral processes, almost sessile or shortly petiolate, very rarely with divided petioles. Tetrasporic forms are similar to the cystocarpic, usually with entire, sometimes with erose margins. The fronds of both cystocarpic and tetrasporic plants are thin and membranous, rather than cartilaginous. The colour is usually dark brown to reddish brown. Hybrids probably occur between this and adjacent species, such as **G. atropurpurea** and **G. apoda** where both species are present. This is one of the commonest of the foliose species, and has been found at many points on the east coast between Dunedin and the Bay of Islands. Plants from the Auckland and the Campbell Islands recorded by the senior author (1909), p. 506, as *G. radula* apparently belong to this species, but are in poor condition. Cystocarpic and tetrasporic plants, September to May.

Dunedin, Timaru, Lyttelton, Double Corner (Amberley), Gore Bay, Kaikoura, Wellington Heads, R.M.L. and H.W.G.; Waipu Cove (E. W. Blackwell!), Bay of Islands (A. McMillan!), Muriwai Bay (M. C. Crookes!).

Tribe IV.—*Heteropodae.*

23. **Gigartina longifolia** J. Ag. (Pl. 19a: Figs. 13-15).

This species was based by Agardh on a few specimens only (pauca tantum specimina) and placed by him close to the species **G. microphylla.** Now, thanks to the good offices of Professor W. A. Setchell, we have several specimens of **G. microphylla** from California. According to Agardh, the terminal fronds of **G. longifolia** are scarcely different from those of **G. microphylla,** though possibly somewhat shorter, and the substance of the leaves somewhat more cartilaginous. The tribe *Heteropodae* contains those members of the genus which bear laminae in a great variety of forms and which are clothed with lingulate appendicules. Further, the intramarginal region is stated to be sterile. Now we have a few speci-

PLATE 16.—*Gigartina lanceata* J. Ag. Photo of Agardh's type.

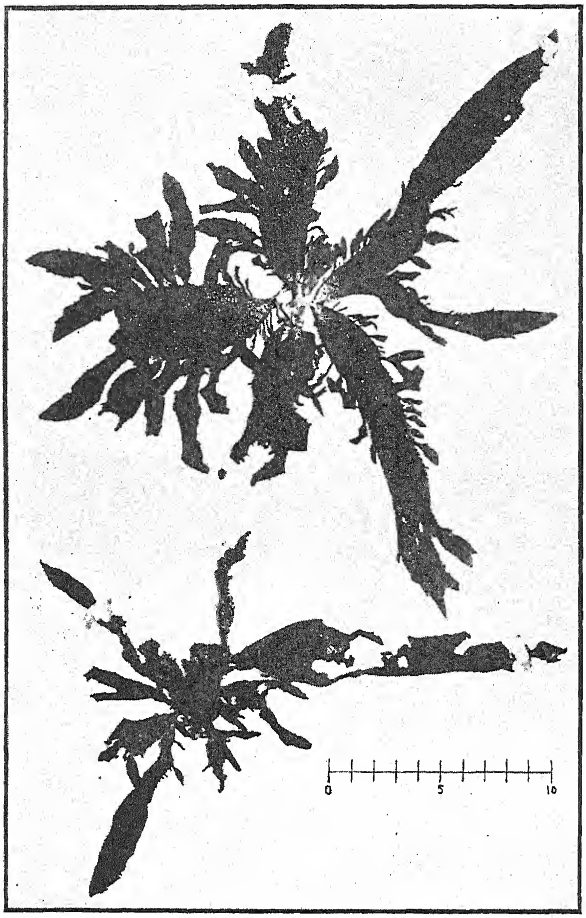

PLATE 17.—*Gigartina atropurpurea* J. Ag. Photo of Agardh's type.

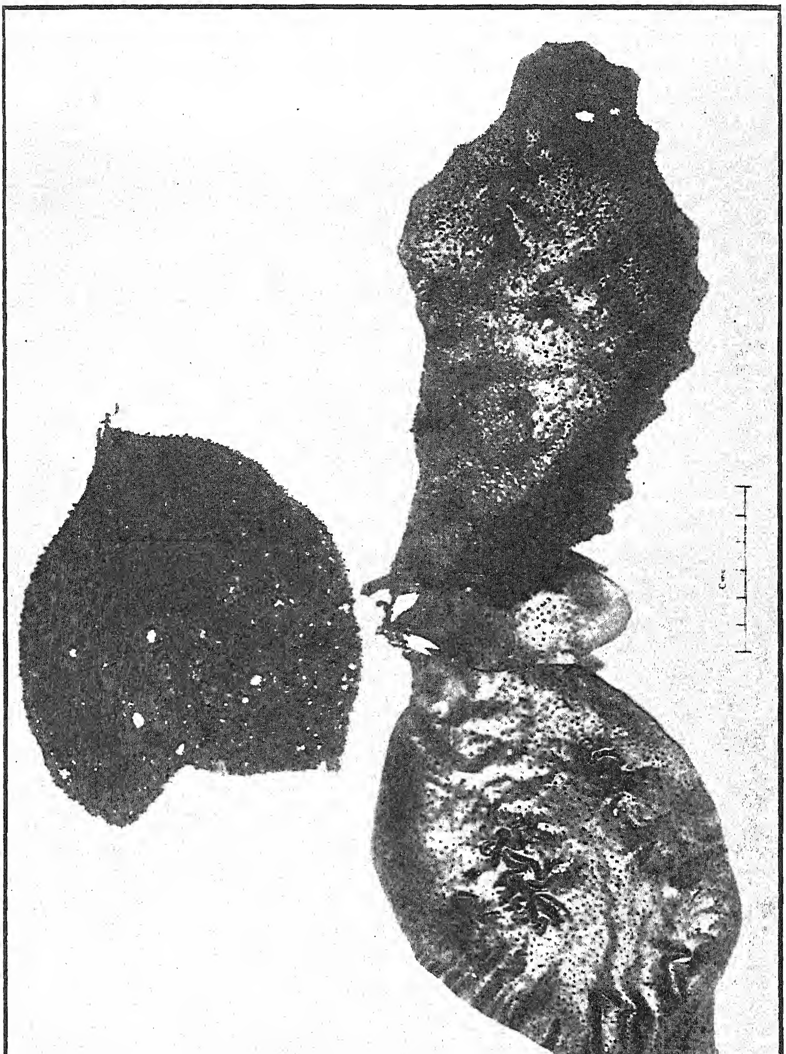

PLATE 18.—*Gigartina apoda* J. Ag. Photo of cystocarpic specimens from Lyttelton.

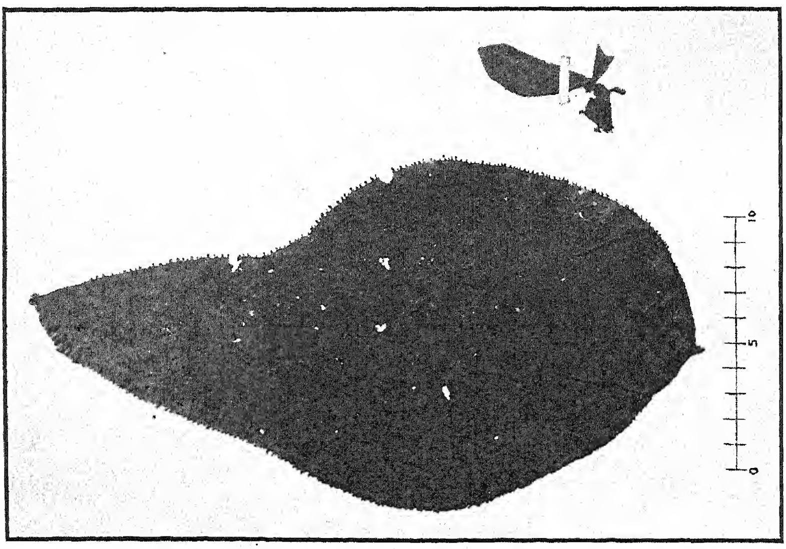

PLATE 19.—*Gigartina circumcincta* J. Ag. Photo of Agardh's type, from Dunedin.

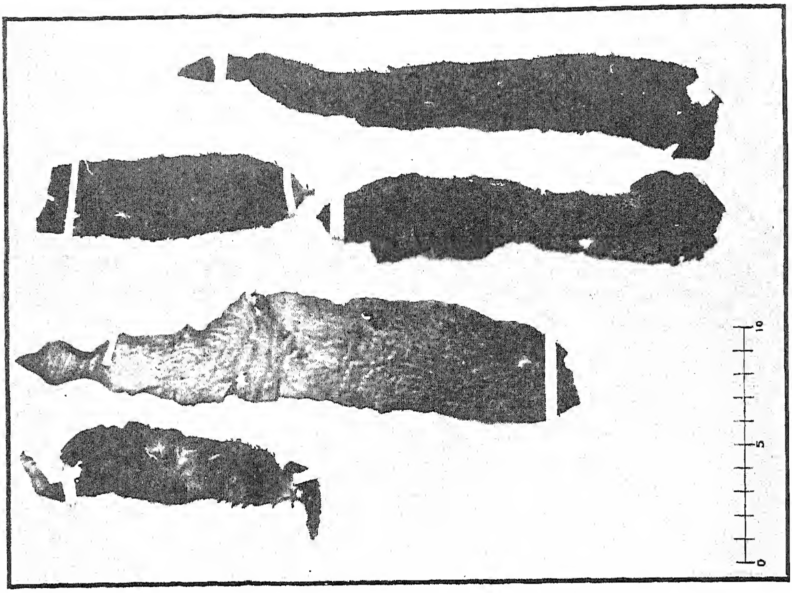

PLATE 19a.—*Gigartina longifolia*. Photo of Agardh's type specimen and a single specimen, from Cape Saunders.

mens from Kaikoura which exactly display all the characters of **G. longifolia** described by Agardh. However, the intra-marginal sterile region is lacking in most of them though distinctly present in one or two. On examining our specimens of **G. microphylla**, we find that the intra-marginal sterile region is there also of irregular occurrence, nor is it obvious in the photograph of the type specimen, so we are not able to regard it as a constant specific character.

Intermediates between the extreme forms of **G. longifolia** and **G. lanceata** may be found. These are possibly hybrids. The type specimen as shown in the photograph (Agardh's Herbarium 23931—1) certainly seems to us to be an intermediate between **G. lanceata** and the New Zealand form similar to the Canadian **G. microphylla** which we have determined as **G. longifolia**. However the extreme forms are certainly quite distinct, yet the inconstancy of the characters and the rarity of the occurrence of **G. longifolia** suggest that we are dealing with a hybrid rather than an unvarying species. On the other hand, the presence in a remote region of a well identified and closely related form, **G. microphylla**, tends to the opposite point of view, viz., to show the disparateness of **G. longifolia**. As the two species in all probability developed separately, they may afford an example of convergent evolution; but at present **G. longifolia** has perhaps not completely separated itself in New Zealand from adjacent forms.

G. longifolia: Plant tufted, sometimes with numerous undeveloped laminae arising from the scutellum. The very short terete stipe usually passes into a long narrow sub-cuneate base without appendages which again passes into a lamina of very varying form, sometimes linear lanceolate, at other times more or less cuneate, obovate, oval, broadly triangular, or variously shaped, often simple, but again once or twice forked or otherwise divided. The surface and margins usually covered with lingulate appendages several millimetres in length. These in some cases develop into folioles 1 cm. to 10 cm. in length arranged pinnately along the margins of the leaf. In other cases, the appendages are often more or less reduced, until they become similar to the bent bristles of **G. lanceata**. Occasionally there is present a narrow sterile intra-marginal band 1 mm. to 2 mm. in width. We have no mature cystocarpic or tetrasporic specimens. The texture of the lamina is usually more or less thin and membranous and never so cartilaginous as in mature specimens of **G. lanceata** which in some of its forms the plant resembles.

The most distinctive characters are the lingulate appendages, the membranous rather than the cartilaginous frond, and possibly also in dried specimens, the dark purple brown of the lamina.

The type specimen is labelled "West Coast of New Zealand," and underneath, "Cape Saunders, Nov. Zel." Presumably it was gathered at Cape Saunders lighthouse, Otago Peninsula.

Gore Bay, R.M.L.; Kaikoura (drift) R.M.L. and H.W.G.

Artificial Key to the Species Described.

A. Non-foliose forms. Fronds not more than 5 cms. across.

I. Thallus not normally distinctly channelled.

(a) Cystocarps not clavate.

*Fronds more or less cylindrical throughout.

Frond without linear leaflets at the apices of the stems: **G. divaricata.**

Frond producing linear leaflets at the apices of the stems: **G. Kroneana.**

**Frond more or less flattened.

Cystocarps on pinnules not genuflexed: **G. macrocarpa.**

Cystocarps on genuflexed pinnules: **G. Chapmanni.**

(b) Cystocarps clavate.

*Cystocarps not produced from the surface of the lamina; but only on the margins.

Frond more or less dichotomously compound: **G. clavifera.**

Frond more or less pinnate: **G. livida.**

**Cystocarps produced from the surfaces of the lamina as well as from the margins.

(a) Branching dichotomous, at least in the cystocarpic fronds.

Cystocarpic fronds 10 cm. to 20 cm. long by 2 mm. to 10 mm. wide: **G. decipiens.**

Cystocarpic fronds 8 cm. to 12 cm. long by 7 mm. to 10 mm. wide: **G. protea.**

Cystocarpic frond becoming ultimately rugose and channelled: **G. marginifera.**

(b) Branching of cystocarpic fronds pinnate: **G. Chauvinii.**

II. Frond always more or less channelled.

Frond deeply channelled throughout with revolute tips: **G. alveata.**

Pinnae and pinnules more or less channelled, often with flattened, not revolute tips: **G. ancistroclada.**

Frond more or less rugose and angular: **G. angulata.**

Frond channelled toward the incurved tips: **G. tuberculosa.**

(**G. laciniata, G. polyglotta, G. insidiosa, G. Burmanni** and **G. flabellata** not seen by us are omitted from this list).

B. Foliose forms. Fronds at least 5 cm. across.

I. Petioles below the frond more or less channelled.

Frond much divided, scarcely cartilaginous, usually with pinnate obovate lobes and without linear or lingulate processes: **G. atropurpurea.**

Frond usually little divided, cartilaginous, margins and sometimes surfaces of frond covered with linear hooked processes: **G. lanceata.**

Frond scarcely cartilaginous, margins and sometimes surface of the frond usually covered with lingulate processes: **G. longifolia.**

II. Petioles not channelled, frond broadly expanded.

(a) Cystocarps developed on both sides of the frond.

Base cordate, frond ovate reniform, irregularly lobed, and rather thin and membranous: **G. rubens.**

(b) Cystocarps more plentifully developed on one side of the frond than the other. Sterile margin usually present.

Frond ovate to orbicular, somewhat cartilaginous: **G. apoda.**

Frond elliptical to rotund, somewhat membranous: **G. circumcincta.**

CONCLUSION.

We recognise that our classification both of foliose and non-foliose forms is very imperfect; but consider that no taxonomic arrangement of such a large number of polymorphic and overlapping forms is possible. The best that can be done is to group them round certain more or less definitely characterised types, and thus enable workers to work in common understanding. We have attempted a key to the New Zealand forms of the genus, which may be of some value to those attempting to identify the species; but we would again warn them that no single character can be considered final, and that large numbers of specimens must be collected before it is possible in many cases to arrive at any identification of the species.

It is hoped in Part III of this paper to describe certain new forms, and give some additional notes on those already described.

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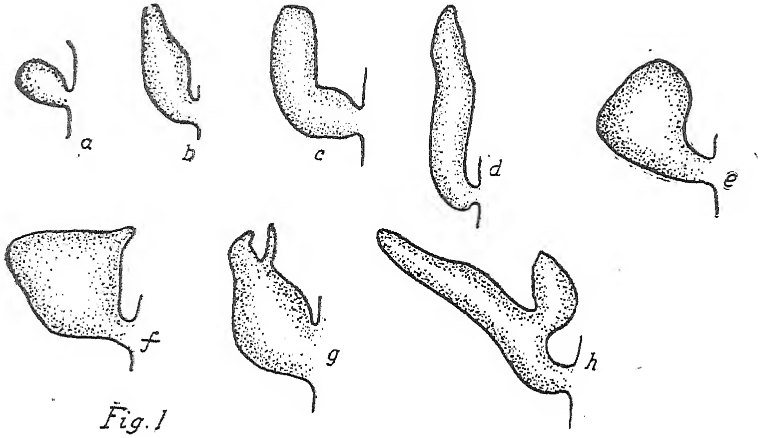


Fig. 1

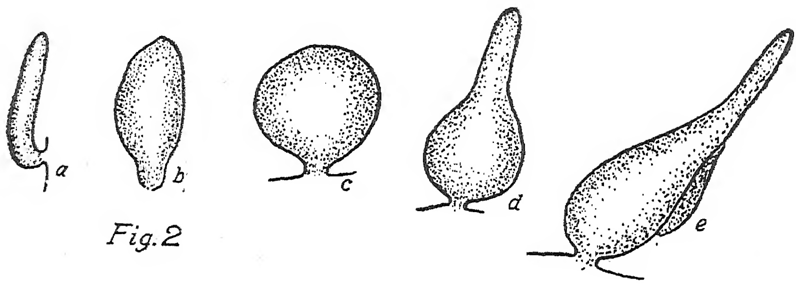


Fig. 2

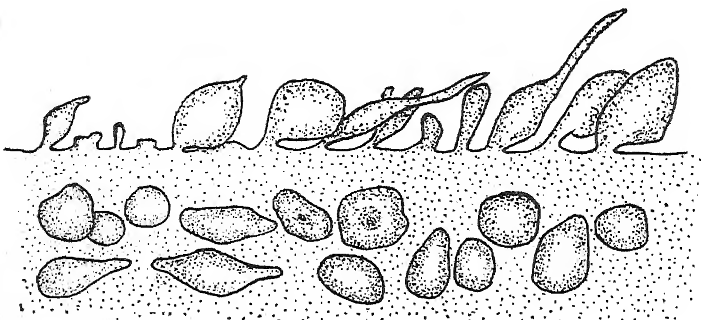


Fig. 3

FIG. 1. (a-h) × 6.—*G. lanceata.* Processes from margin of frond.

FIG. 2. (a-e) × 6.—*G. lanceata.* Processes from lamina of frond.

FIG. 3. × 6.—*G. lanceata.* Portion of margin of young cystocarpic frond showing an intramarginal sterile region (unusual form).

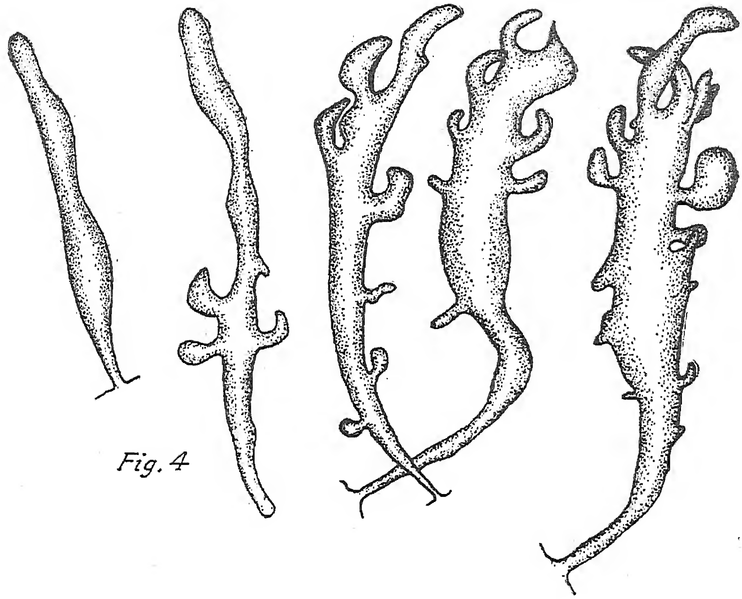


Fig. 4

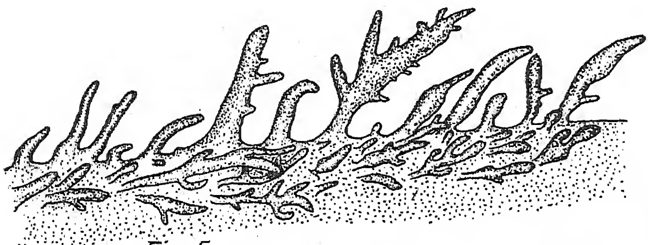


Fig. 5

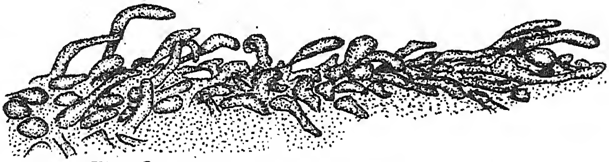


Fig. 6

FIG. 4. × 12.—*G. lanceata.* Fully developed sterile processes from margin and lamina.

FIG. 5. × 6.—*G. lanceata.* Portion of margin showing processes similar to those of FIG. 4.

FIG. 6. × 6.—*G. lanceata.* Portion of margin of densely clothed plant.

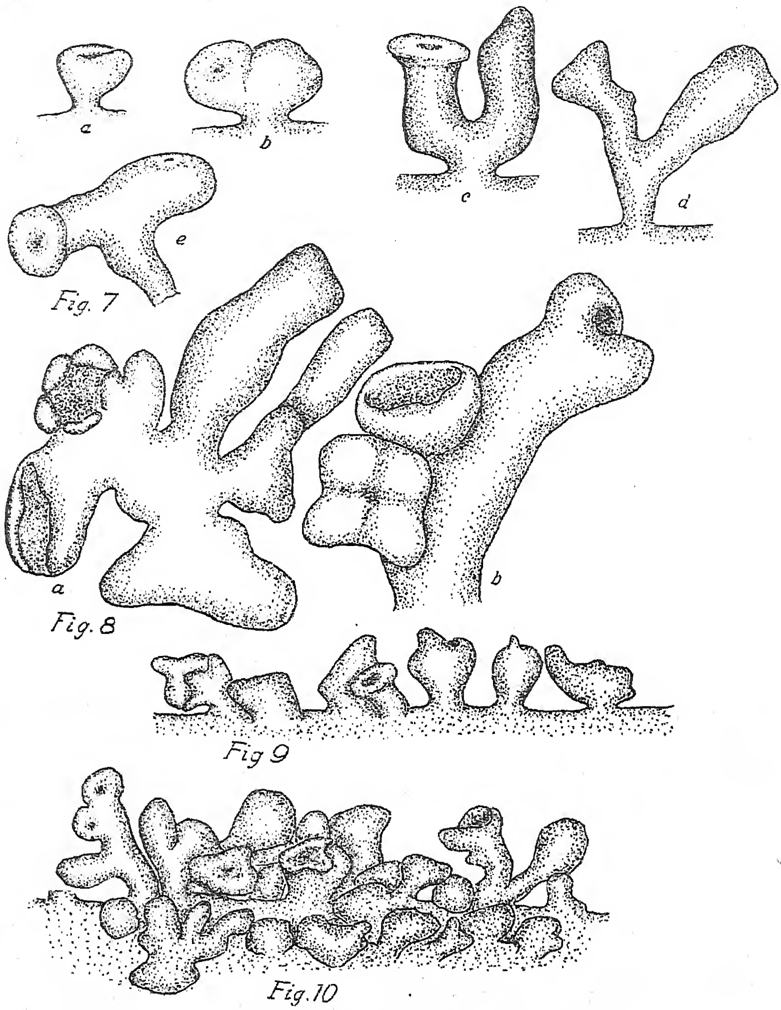


Fig. 7. (a-e) × 8.—*G. apoda.* Developing cystocarps.

Fig. 8. (a-b) × 12.—*G. apoda.* Mature cystocarpic processes.

Fig. 9. × 6.—*G. apoda.* Margin of plant bearing cystocarps as in Fig. 7.

Fig. 10. × 6.—*G. apoda.* Margin of plant bearing cystocarpic processes as in Fig. 8.

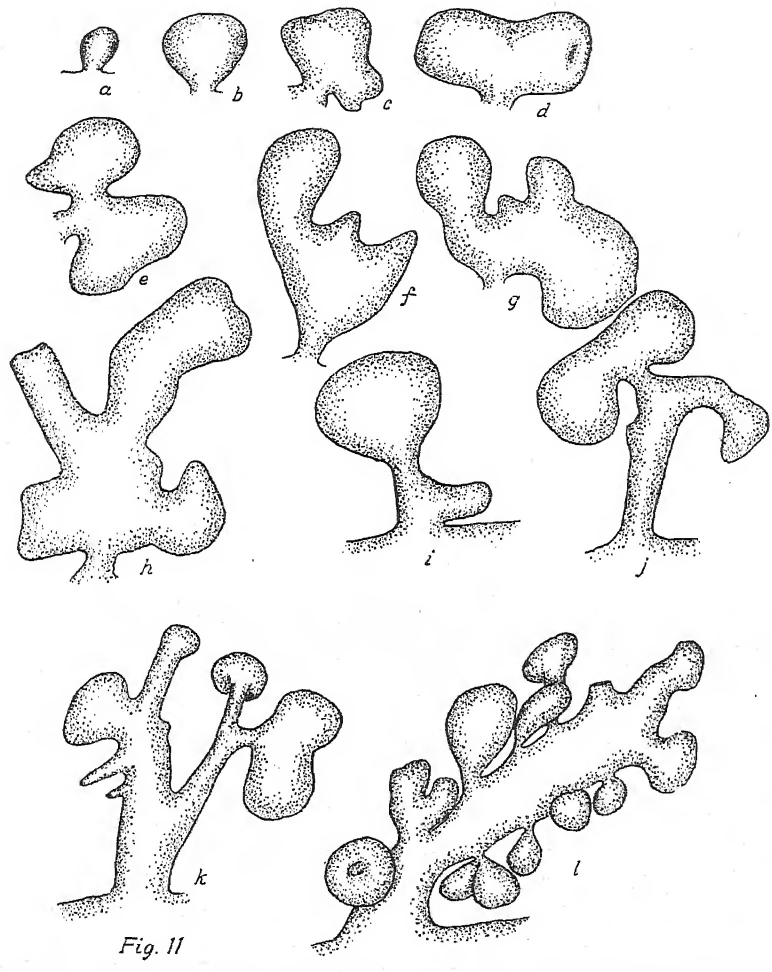


FIG. 11. (a-l) × 10.—*G. circumcincta.* Development of cystocarpic processes.

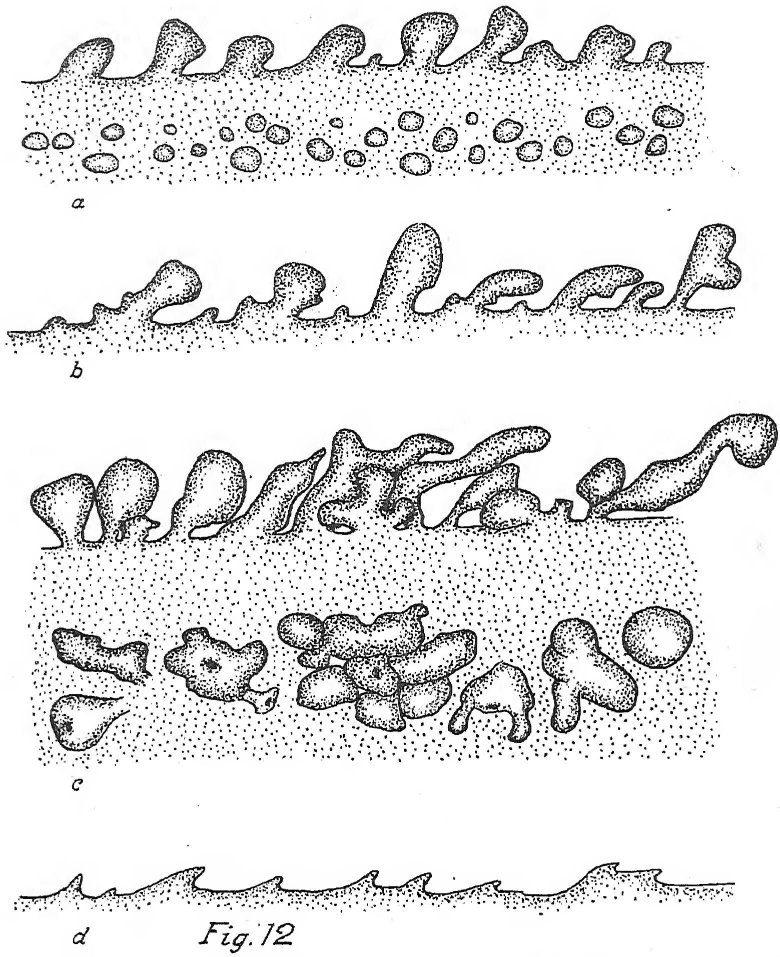
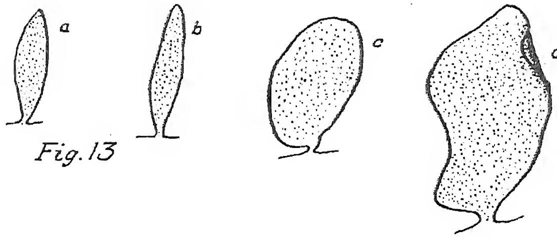
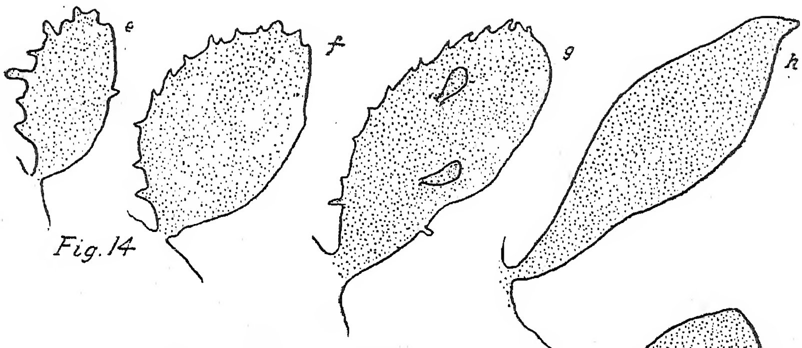


Fig. 12. × 4.—*G. circumcincta.* (a-c) from young to mature plants showing intramarginal sterile bands; (d) margin of sterile plant.





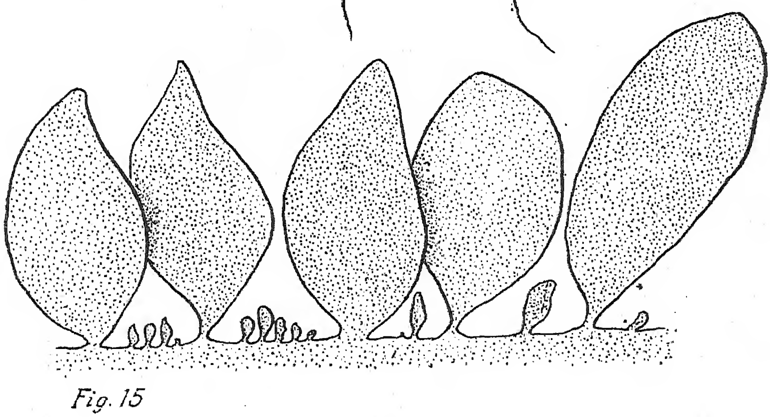


FIG. 13.—*G. longifolia.* FIG. 13 × 6 (a-d) lingulate processes from disc.
FIG. 14. (e-h) × 4.—More highly developed lingules from the margin.
FIG. 15. (i) × 3.—Portion of margin.

Description of Tertiary Brachiopoda from New Zealand.

Part 1.

By R. S. Allan, M.Sc. (N.Z.), Ph.D. (Cantab.), National Research Scholar.

[*Read before the Otago Institute, 8th July, 1930; issued separately, 30th September, 1931.*]

Recent field-work in various parts of New Zealand has resulted in the discovery of several new species of Tertiary brachiopods. Some of these are here described.

Rhizothyris labiata n. sp. (Pl. 21, Fig. 2).

Description.—Shell large for the genus, broadly elliptical, sides convex, slightly tapering in front but broadly truncated. Ventral valve strongly convex, with the greatest convexity about the posterior third; dorsal valve moderately convex. Anterior commissure incipiently sulcate. Beak of medium length, suberect. Beak-ridges sharply carinate, merging into the sides. Foramen permesothyrid, labiate, oval, oblique. Symphytium of moderate height, but very wide. Lateral palintropes narrow. Hinge-line broad, but gently curved. Shell smooth, except for growth-lines. Punctation fine and dense.

Hinge-teeth large and strong, supported by huge, swollen bases. Ventral muscular impressions large. Dorsal valve greatly thickened posteriorly. Dental sockets large and deep. Inner socket ridges indistinctly fused against the crural bases anteriorly, and running back as a thin plate to coalesce with the posterior part of the cardinal process. The two structures project, in ear-like processes, beyond the dorsal hinge-line. Crural bases enormously swollen, divided medially by a groove running from the top of the septum to the base of the cardinal process. The latter is very large, and completely fills the hinge-trough. The upper (ventral) surface is flat, but two ridges run back to the ears. Laterally there are grooves bounded by the sides of the cardinal process, the posterior surface of the crural bases, and the inner sides of the socket ridges. Between the ear-like processes and resting on the posterior surface of the cardinal process, is a striated muscular pit. The crura are attached to the crural bases, close together, above the septum. The latter is short, considerably thickened below, but plate-like above, and at its anterior end. It is fused posteriorly against the crural bases, but does not bifurcate. Muscular impressions in a deep pit. Loop magellaniform, extending two-thirds of the whole length.

Dimensions of holotype: Length, 45 mm.; breadth, 38 mm.; thickness, 24 mm.

Type locality: Clifden, Southland. Horizon C on the east side of the Waiau River.

Material: The species is very abundant and perfectly preserved.

Mr F. J. Turner, of Otago University, to whom I owe the pleasure of describing this fine species, collected some 30 specimens. It also occurs, but more rarely, in horizons B and D on the same side of the river. Horizons B, C, and D are, as a whole, the equivalent of Band 7 of Dr Finlay's papers on Clifden. The age is the same as that of the Uppermost Mount Brown limestone of the Weka Pass district.

Affinities.—*R. labiata* n. sp. differs from *R. elliptica* Thomson in shape, and in the character of the foramen. It is not likely to be confused with any other species.

Rhizothyris longitudinalis n. sp. (Pl. 20, Fig. 5; Pl. 22, Figs. 5-7).

Description.—Shell elongate-elliptical, hinge-line broad and little curved, sides very slightly convex, front rounded. Valves moderately convex. Anterior commissure almost straight or incipiently sulcate. Beak prominent, nearly straight, little produced dorsally of the hinge-line. Beak-ridges pronounced, forming an obtuse-angle with the sides. Foramen permesothyrid, of moderate size. Symphytium high and wide.

Dimensions of holotype: Length, 50 mm.; breadth, 34 mm.; thickness, 23 mm.

Type locality: Clifden Quarry, Clifden, Southland, in a rubbly, yellow-brown limestone. The species is comparatively rare.

Age: Hutchinsonian.

Affinities.—*R. longitudinalis* n. sp. agrees closely with *R. elliptica* Thomson (1920, p. 372, Pl. 22, Fig. 1; Pl. 23, Fig. 3), but differs in being more elongate. With *R. elongata* Thomson (1920, p. 372, Pl. 22, Fig. 11; Pl. 23, Fig. 11) the new species agrees in elongation, but differs in being broadly rounded anteriorly. Both *R. elliptica* Thomson and *R. elongata* Thomson are associated with this species at Clifden.

Rhizothyris rhizoida (F. W. Hutton 1905). (Pl. 20, Fig. 2; Pl. 22, Fig. 4).

1905. *Bouchardia rhizoida* Hutton. *Trans. N.Z. Inst.*, 37 (June), p. 480, Pl. 40, Fig. 7.

1915. *Rhizothyris rhizoida* (Hutt.) J. A. Thomson, *Trans. N.Z. Inst.*, 47, p. 398, text-fig. 5 a-b. (5a = holotype). (Not 5d = *R. elliptica* Thomson 1920).

1927. *Rhizothyris rhizoida* (Hutt.) Thomson, *N.Z. Board Sci. & Art.*, Man. No. 7, pp. 278-9, text-fig. 93 a-b.

Description of topotype: Shell of medium size for the genus, triangular, sides gently convex, rapidly tapering, front pointed. Hinge-line broad, gently curved. Beak very prominent, erect, produced dorsally of the hinge-line. Beak-ridges strongly carinate, forming an obtuse-angle with the sides. Foramen of moderate size, permesothyrid, labiate. Symphytium high and wide. Lateral palintropes prominent, almost flat. Anterior commissure nearly straight but incipiently sulcate. Both valves strongly convex. Shell smooth. Punctation fine and dense.

Dimensions of topotype: Length, 36 mm.; breadth, 28 mm.; thickness, 21 mm.

Type locality: Weka Pass district. (Probably from the Main Mount Brown limestone which may hereafter be considered the type horizon).

Remarks.—J. A. Thomson (1920, p. 371) stated that shells exactly matching the holotype are rare; and he enlarged the species "to include those shells intermediate in elongation between *R. scutum* and *R. elongata* (both of Thomson 1920) which are moderately elongate, with a slightly curved hinge-line nearly the breadth of the shell, and a marked taper. These shells are moderately to strongly convex, and always show some folding."

The writer is at present unable to follow Thomson in this redefinition, and would restrict *rhizoida* to shells agreeing with the holotype. The shell figured by Thomson (1920, Pl. 22, Fig. 6) is not typical.

As thus restricted *R. rhizoida* is known to me from two localities only, viz., the Main Mount Brown limestone, Weka Pass; and Clifden Quarry, Clifden, Southland, in a rubbly limestone. Both horizons are of Hutchinsonian age.

Rhizothyris trigonalis n. sp. (Pl. 20, Fig. 3; Pl. 22, Figs. 1-3).

Description.—A *Rhizothyris* closely related to *R. rhizoida* (Hutt.), but with a rather wider hinge-line, a much shorter beak, a low wide symphytium, and a small foramen.

Dimensions of holotype: Length, 34 mm.; breadth, 29·5 mm.; thickness, 19 mm.

Type locality: Limehills, Winton. Collected by Dr F. H. McDowall. The species also occurs in the Hutchinsonian greensands of Hutchinson's Quarry, Oamaru.

Pachymagas turneri n. sp. (Pl. 21, Fig. 1; Pl. 22, Figs. 8-10).

Description.—Shell large for the genus, broadly ovate, sides convex, front tapering but broadly truncated. Valves strongly and evenly convex. Hinge-line broadly rounded. Ventral valve with a distinct, wide, flat keel. Anterior commissure with a broad shallow sulcation. Beak large, erect, little produced dorsally of the hinge-line. Foramen mesothyrid, attrite, rather large. Beak-ridges not strongly carinate. Symphytium high but narrow. Lateral palintropes wide, concave. Punctation fine and dense.

Dimensions of holotype: Length, 56 mm.; breadth, 45 mm.; thickness, 28 mm.

Type locality: Rubbly limestone, Clifden Quarry, Clifden, Southland.

Age: Hutchinsonian.

Remarks.—The holotype was the only specimen of this species collected by the writer, but Mr F. J. Turner, of Otago University, has since obtained a second perfect example from the same locality.

Fig. 1.

Fig. 2.

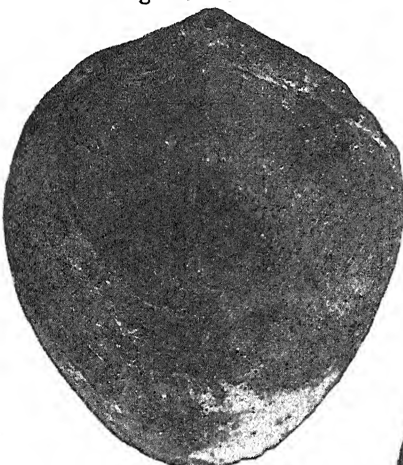


Fig. 3.

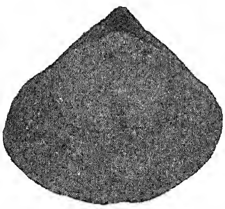


Fig. 4.

Fig. 5.

PLATE 20.

Fig. 1.—*Terebratella clifdenensis* n. sp. Holotype. x2.
Fig. 2.—*Rhizothyris rhizoida* (Hutton). Topotype. x2.
Fig. 3.—*Rhizothyris trigonalis* n. sp. Holotype. x2.
Fig. 4.—*Tegulorhynchia sublaevis* (Thomson). Topotype. x3.
Fig. 5.—*Rhizothyris longitudinalis* n. sp. Holotype. x1·5.

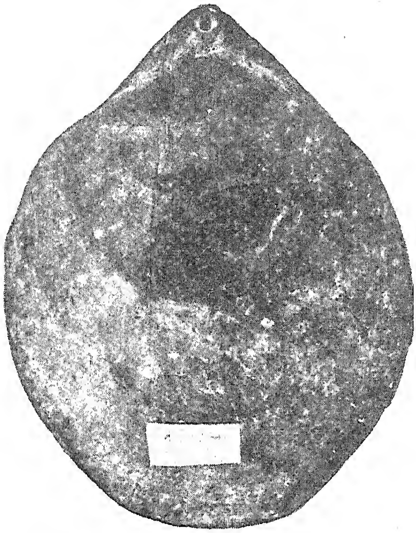


Fig. 1.

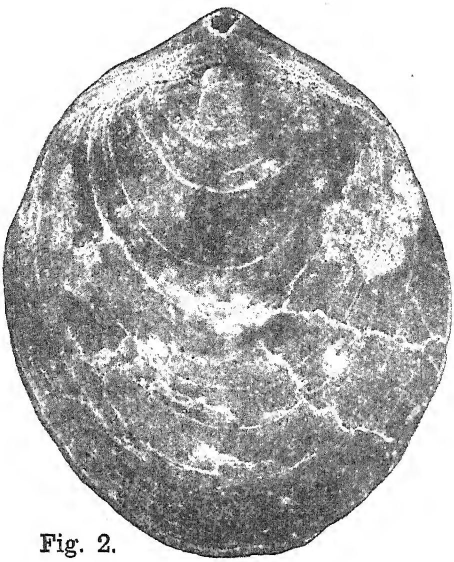


Fig. 2.

PLATE 21.

FIG. 1.—*Pachymagas turneri* n. sp. Holotype. x 1·25.

FIG. 2.—*Rhizothyris labiata* n. sp. Holotype. x 1·7.

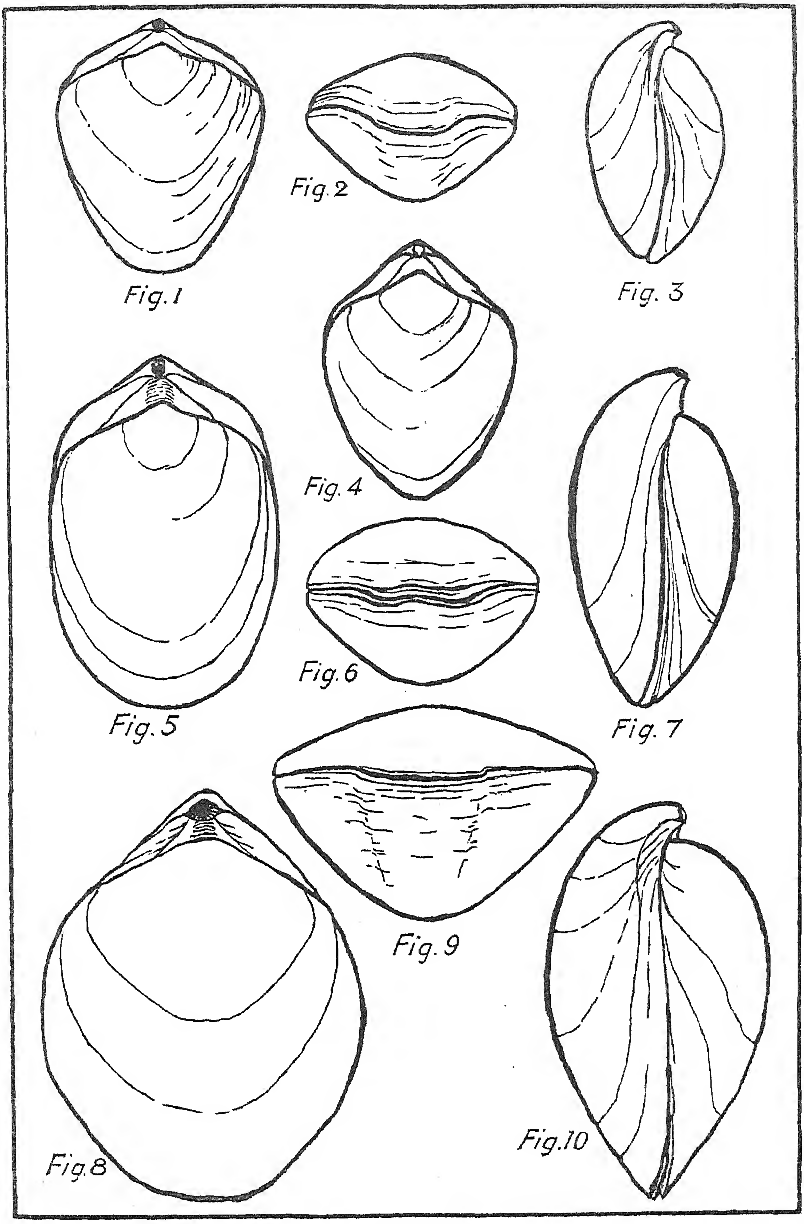


PLATE 22.

Figs. 1-3.—*Rhizothyris trigonalis* n. sp. Holotype. x 1.
Fig. 4.—*Rhizothyris rhizoida* (Hutton). x 1.
Figs. 5-7.—*Rhizothyris longitudinalis* n. sp. Holotype. x 1.
Figs. 8-10.—*Pachymagas turneri* n. sp. Holotype. x 1.

Affinities.—*P. turneri* n. sp. is a very distinct species which does not seem to be closely related to other members of the genus known from New Zealand.

Terebratella clifdenensis n. sp. (Pl. 20, Fig. 1).

Shell of medium size, broadly ovate, greatest width slightly posterior to the middle line, sides rather strongly convex, tapering anteriorly, and narrowly truncated in front. Ventral valve strongly carinate from the umbo to the anterior margin; dorsal valve flattened with a shallow median trough. Anterior commissure strongly sulcate. Beak prominent, suberect. Beak-ridges well defined. Foramen large, oval, submesothyrid. Deltidial plates almost conjoint, separated by a groove from wide, slightly concave palintropes. Punctation fine and dense. Shell smooth, except for growth-lines. Interior unknown.

Dimensions of holotype: Length, 27 mm.; breadth, 22 mm.; thickness, 12 mm.

Type locality: Clifden, Southland, Band 6A.

Remarks.—A very distinct new species, of which two specimens only are known. The holotype was collected by the writer, a paratype by Dr H. J. Finlay. This species may prove to belong to *Magella* which differs from *Terebratella* only in loop characters.

Tegulorhynchia sublaevis (J. A. Thomson, 1918). (Pl. 20, Fig. 4).

1918. *Hemithyris sublaevis Thomson*. in J. Park, *N.Z. Geol. Surv. Bull.* No. 20, p. 117, not figured.

1923. *Tegulorhynchia sublaevis* (Th.), Chapman and Crespin. *Proc. Roy. Soc. Vict.*, 35 (N.S.), pp. 188-9, not figured.

Description (Based upon a manuscript diagnosis by J. A. Thomson; and on study of topotypes).—Shell small, slightly broader than long, sides rounded, front somewhat variable but not departing much from a straight line. Dorsal valve strongly convex, especially near the umbo, with a broad, slightly raised, median anterior fold. Ventral value much less convex, flattened anteriorly, with a broad median anterior sinus. Anterior commissure strongly uniplicate. Hinge-line broadly rounded. Beak short, bluntly pointed, erect. Foramen rather large, hypothyrid. Deltidial plates disjunct. Surface ornament consisting of a variable number of very low, rather fine costae, which are not scaly and are often almost obsolete. The multicostation is best expressed on young shells, which are relatively less convex, and possess more acute beaks. The growth-lines are prominent on older shells and are crowded anteriorly. Internal details as for the genus. (See Thomson, 1927, pp. 152-3).

Dimensions of holotype: Length, 10 mm.; breadth, 10·5 mm.; thickness, 7 mm.

Type locality: Everett's Quarry, Kakanui. The species is abundant in the Kakanui limestone.

Age: Upper Ototaran.

Affinities.—*T. sublaevis* (Thomson) belongs to the same group as *T. depressa* (Thomson), but differs from that species in being more narrowly and strongly folded; and in possessing non-imbricate costae.

Literature Cited.

Chapman, F. & Crespin, I. 1923. The Austral Rhynchonellacea of the "Nigricans Series," with a special description of the new genus *Tegulorhynchia*. *Proc. Roy. Soc. Vict.*, 35 (N.S.), pp. 170-93, Plates 11-13.

Hutton, F. W. 1905. Revision of Tertiary Brachiopoda of New Zealand. *Trans. N.Z. Inst.*, 37 (June), pp. 474-81, Plates 45-6.

Thomson, J. A. 1915. Brachiopod Genera: The Position of Shells with Magaselliform Loops, and of Shells with Bouchardiform Beak Characters. *Trans. N.Z. Inst.*, 47 (July 12), pp. 372-403.

—— 1918. (Brachiopoda of the Oamaru District). In J. Park, *N.Z. Geol. Surv. Bull.* No 20, pp. 117-119.

—— 1920. The Notocene Geology of the Middle Waipara and Weka Pass District, North Canterbury, New Zealand. *Trans. N.Z. Inst.*, 52 (August 9), pp. 322-415, Plates 16-27.

—— 1927. Brachiopod Morphology and Genera. (Recent and Tertiary). *N.Z. Board Sci. & Art, Man.* No. 7. 338 pp., 103 figs., two plates.

The Tertiaries at the Hurunui Mouth.

By R. SPEIGHT, M.Sc., and GEO. JOBBERNS, M.A.

[*Read before the Philosophical Institute of Canterbury, 3rd June, 1931; with map, photographs, and sections; issued separately, 30th September, 1931.*]

IN the year 1928 the authors of this paper published (*Trans. N.Z. Inst.*, vol. 59, 1928, pp. 213-31) an account of a break in the Tertiary sequence of North Canterbury at the base of the Mount Brown Series. The original district examined in this connection was that near the mouth of the Hurunui River, where the evidence for such a break was undoubted, but other districts in North Canterbury were investigated subsequently and the authors were convinced that the break was of wide distribution. Since the issue of the paper some private criticism has been directed against our interpretation of the section at the mouth of the Hurunui, and therefore the locality has been examined in more detail, especially those horizons below the break. Advantage has been taken of low-river levels, of changes in the position of the stream, and the uncovering of the banks by river erosion, to obtain a better idea of the stratigraphy, and parts otherwise inaccessible bordering on the deep river, have been approached by means of a boat. Thus the sections have been more thoroughly examined than previously. While changes in interpretation are now made in certain particulars, the main contention advanced in the former paper that the Mount Brown beds are unconformable to the lower members of the Tertiary Series stands in its entirety, and the only modifications are those concerning the identity and relations of the beds at a lower stratigraphical horizon. These conclusions have some bearing on the relations of the Tertiary sequence in the North Canterbury area, and therefore the subject is now being submitted for re-consideration.

GENERAL ACCOUNT OF THE LOCALITY.

(See Map and Plates 23 & 24).

About a mile from the sea-coast at the mouth of the Hurunui, the river runs through a somewhat shallow gorge incised in a spur of greywacke reaching south-west from the mass of Mt. Seddon (984ft.), and both above and below the gorge the Tertiaries are developed on both sides of the river. The road crosses from the north to the south bank by a bridge at the narrowest part of the gorge. Above and below the bridge the stream flows over a gravel bed considerably wider than near the bridge, and has on its upstream side bordering banks with a general height of about 40 feet above stream-level, while downstream the banks on the south side rise to a high cliff (500ft.) and then sink in steps formed of well-defined wave-cut platforms to sea-level (see Plate 23). On the north side of the river below the bridge the terrace continues on the same level as upstream of the bridge, but when it reaches nearly to the coast-line it swings round

and runs for nearly half a mile parallel with the shore, with a narrow lagoon or channel at its base formed by the diversion of the river in a northerly direction by the strong set of the sea waves and currents from the south (see map and Plate 24). This lagoon continues north for a distance of about half a mile before the stream breaks through the bank, and the position of the outlet varies owing to the relative influence of floods in the river and of storms from the sea which pile the shingle across the river-mouth. During such storms the waves may break across the lagoon against the face of the cliff on its inner margin. The height of this cliff is approximately 40 feet, but half way along it rises to a higher terrace, and this continues with slightly increasing height till its surface merges into the southerly slopes of Mount Seddon. The general arrangement of the Tertiaries is in the form of a marginal fringe to the greywacke mass of this hill, for they swing round its base continuously from the coast just north of the mouth of the Hurunui past the south end of the bridge, and then upstream and on over the ridge to the north-east, and finally reach the sea-coast again at Port Robinson and Gore Bay.

SUCCESSION OF BEDS. (See Sections Nos. 1, 2, 3; also Map).

The succession of beds is substantially the same as that given on page 214 of our paper, but it may be amplified slightly from combinations of the sequence displayed upstream from the bridge and also on the face of the cliff near the lagoon. Resting on a surface of greywacke is the following:—

1. *Sandstone* and *Shaly Beds*, repeatedly interstratified, the former about one foot in thickness, the latter about three inches, exposed in the river bank above the bridge for about 80 yards. They strike N.-S. approx. and have a westerly dip of 10°. At their base is a conglomerate containing greywacke fragments.

On the lagoon face or just beyond it the beds in a corresponding position resting on greywacke are composed of non-glauconitic concretionary layers of sandstone, with interstratified layers containing glauconite, and sulphur sands with white efflorescence. They strike N. 50° E. and dip to the south-east at angles of 15°. They are exposed for 35 yards at the base of the cliff, and their thickness is probably in excess of 30 feet. They are in all probability the stratigraphical equivalent of beds of similar lithological character exposed in the lower part of the Jed River before it enters Gore Bay.

2. *Greensands*, very glauconitic near the base, less glauconitic at higher levels, and passing up into a greensandy marl. Upstream on the south bank they have a layer of greywacke pebbles at the base. They appear on the opposite bank both above and below the bridge, where the contacts are obscured, and also on the face of the lagoon cliff, where they show for a distance of 40 yards. (See Sections 1, 2, and 3).

3. *Marl* (= Chalk Marl). In the lower parts it is definitely glauconitic and sandy, but it soon shows harder layers, white in colour, of more calcareous material, with a flaky fracture. Higher still it loses its definite stratification, and becomes grey in colour,

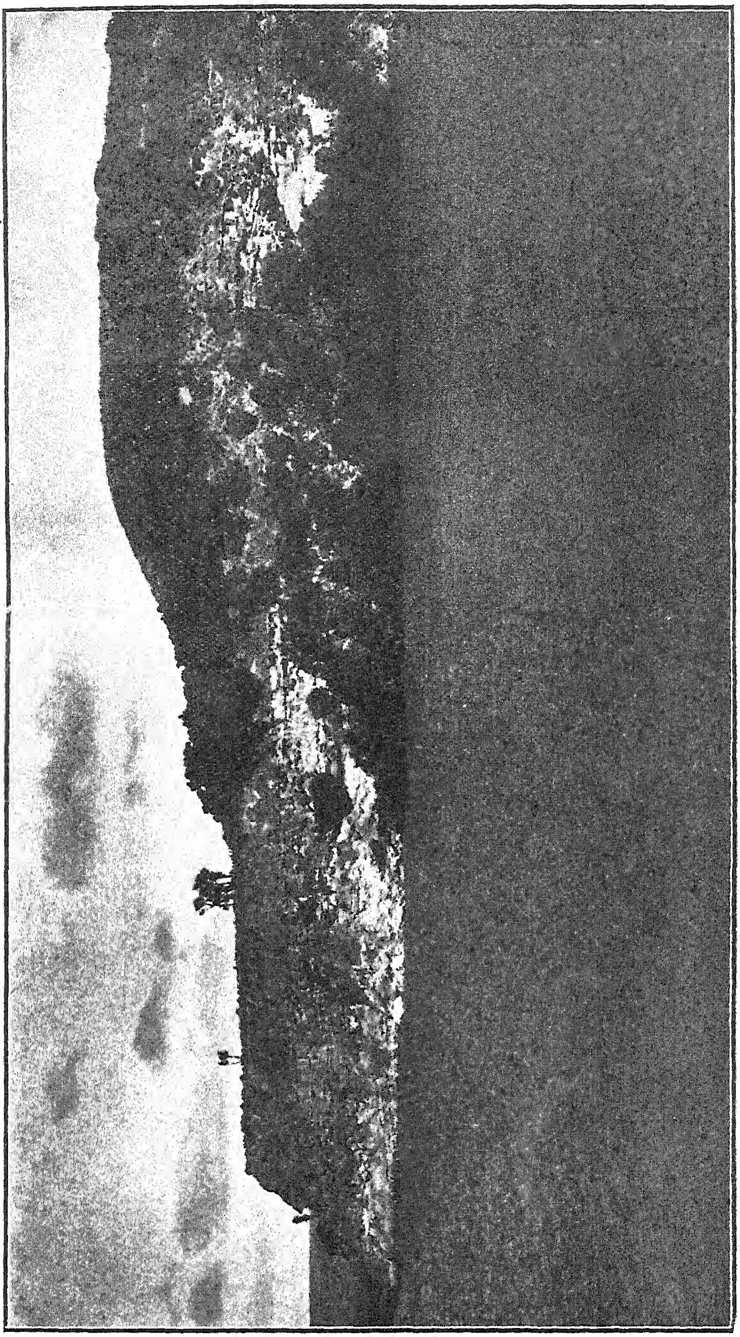


PLATE 23.—View across the mouth of the river, showing two old shore platforms, and Mount Brown beds resting on Hurunui Marl. The contact is clearly visible about one-third of the way up the cliff, at the line where there is a change from whitish to brown.

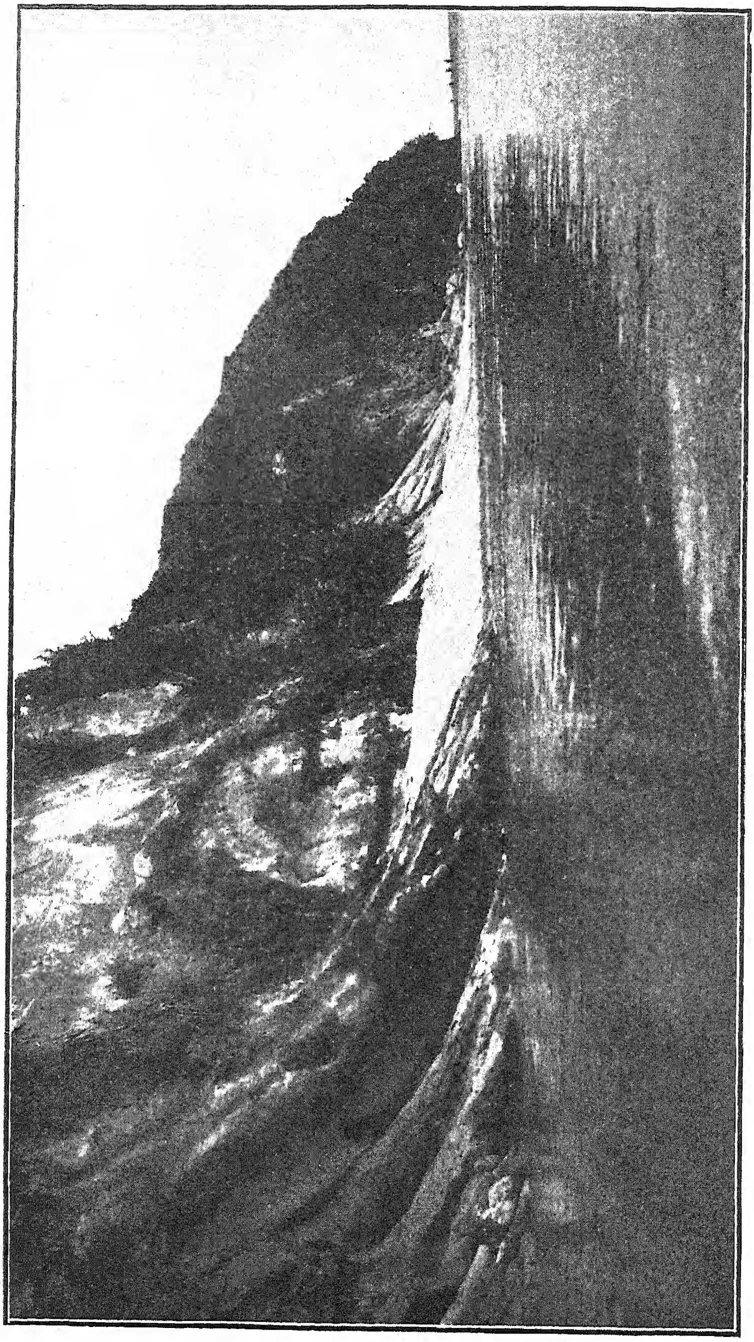


Plate 24.—View along the cliff face fronting the lagoon. The beds in the left-hand corner are Weka Pass Stone and the covering beds the Mount Brown Series.

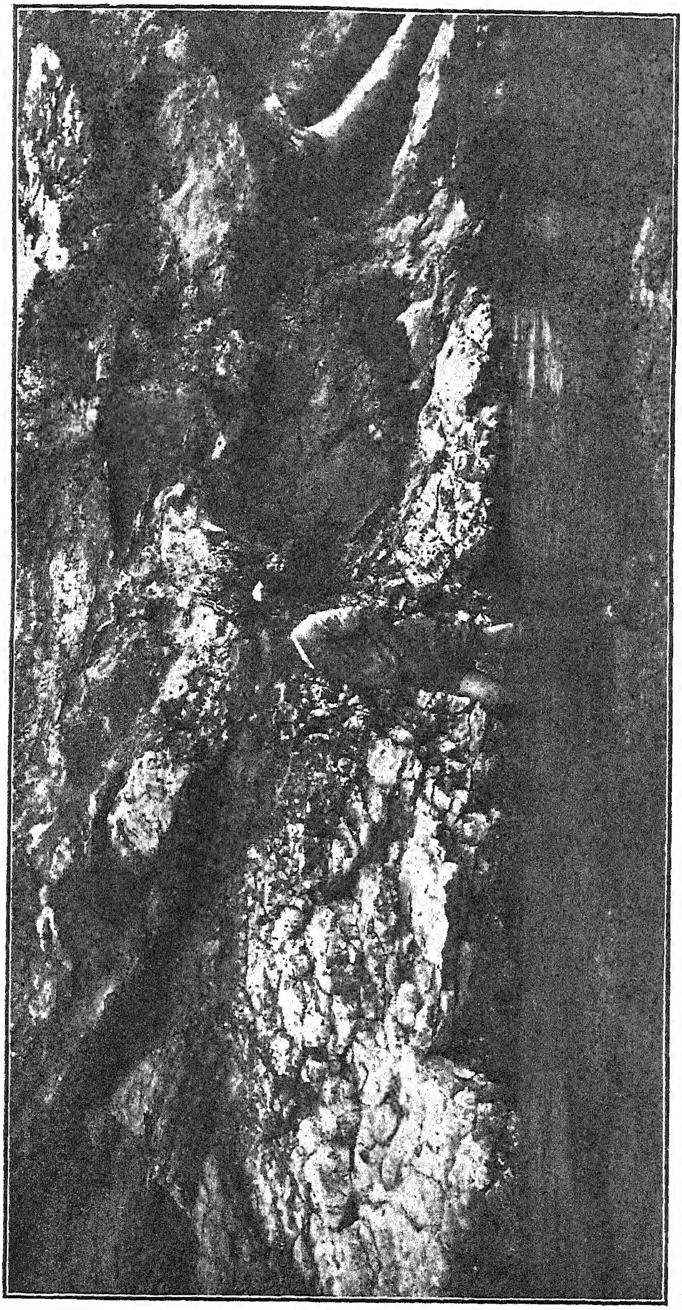


PLATE 25.—Amuri Limestone at the base, covered with Weka Pass Stone, shown in the right-hand corner; the top of the picture is filled with Mount Brown beds, which contain large fragments of Amuri Limestone and Weka Pass Stone. A fault slopes diagonally up the print from right to left. This picture is taken looking approx. N.W. at the cliff face from a point close to water-level in the lagoon.

and after that it takes on a white, flaky, argillaceous limestone facies with interstratified layers of softer, more marly material till it passes up into the Amuri Limestone. This is developed on both sides of the river upstream. On the south bank it strikes nearly N.-S. with slight variation in direction owing to local deformational movements, and a dip to the west at low angles. It is much faulted and shows slickensided surfaces and local puckering and crumpling. Across the river it strikes more to the east, the beds swinging round the western base of Mt. Seddon.

This bed is exposed on the lagoon face for 270 yards, and where it is solid it has a N.-S. strike and a dip to the west of 15°, but the whole face here is much slipped and its relations are obscure. It is terminated towards the south by a fault, with an apparent overthrust from the south, but the fault may be an ordinary normal fault with a downthrow to the south. The marl also occurs below the bridge on both sides of the river. On the north side the exposure is very much obscured with slips except in the higher horizons, where it looks like the higher horizons on the lagoon face. This bed strikes towards this face under the plantation of the reserve, and it occurs in the gully between the plantation and the bank upstream with the same strike, but it is uncertain whether it reaches the face of the lagoon cliff in this part of the section. A marl does appear there but it is reasonable to think that it is the Hurunui Marl, as will be shown later.

Similar beds occur at river level on the south bank under the high cliff where they run out in submerged reefs, striking E. 25° N. and dipping to the south at an angle of about 5°. The beds are also exposed a few feet above river level. They show at this point hard calcareous bands, about one foot thick, with flaky chalky bands interstratified. These are just opposite the exposure on the north bank. (See Section No. 2).

Further upstream towards the bridge, but separated from the occurrences downstream, the marl occurs lying on greensand-marl, which in turn lies on greensand. The marl can be traced nearly halfway up the hillside in a line with the bridge, and it apparently strikes in the direction of the beds below the bridge on the north side of the stream as if they were connected up beneath its bed. (See Section No. 1).

4. *Amuri Limestone.* Apart from the beds transitional from the Chalk Marl, which are thick, the Amuri Limestone as typically developed has a thickness of only a few feet. It shows the quadrangular fracture, and lenses of calcareous greensand which are characteristic of the beds near Kaikoura. It outcrops on both sides of the river above the bridge, on the south bank striking N.-S. and dipping at an angle of 20° to the west. It swings round across the river so that the strike is more easterly. The only place where it occurs in position on the lagoon face is about 280 yards from the corner of the road along the cliff, where as the result of folding it shows for a few feet in the core of an anticline just above water. (See Plate 25 and Section 3). The summit of the arch is faulted,

the hade of the fault being 65° to the north-east, and the downthrow is also in that direction; the amount of displacement cannot be more than a few feet. The angle of the contact of the Amuri Limestone with the overlying Weka Pass Stone is 30°. The fault at the junction of the Chalk Marl, about 200 yards farther north, apparently cuts out the Amuri Limestone, so that it cannot be seen, though fragments occur in a breccia alongside the fault. These are the only two occurrences that are visible, and to account for their absence we can only suggest that downstream from the bridge the limestone either lies beneath the river-bed and cannot be seen, or that it has been removed by erosion. We have come to the conclusion that the masses on the south bank near the point, large though they undoubtedly are, are merely floaters.

5. *Nodular Layer.*—This is well developed upstream in its normal position, but it is not so definite on the lagoon frontage, the nodules being distributed freely through several feet of the Weka Pass Greensand, and not concentrated into a definite layer.

Unconformity.—Here comes a break in the stratification, the evidence for which will be considered in connection with the next overlying bed.

6. *Calcareous Greensand* (= Weka Pass Stone).—This occurs upstream on the south side of the river in its normal position, but the greatest development in the locality occurs in the lagoon cliff, where it extends for fully 200 yards along the front. (See Section No. 3). The strike and dip vary. At the northern boundary of the occurrence the beds have a strike N.E.-S.W. and a south-easterly dip of 25°. Just past the point to the south of this, near a large cave, the strike is N. 5° E. and the dip easterly at an angle of 15°. The beds are here bent up into an arch with a steep south-westerly limb. The strike again lies parallel to the shore, its direction being N.E. and the dip south-east at an angle of 35°, while a little farther on the strike becomes N. 70° E. and the dip south-easterly at an angle of 20°. A chain further on the strike is practically E.-W., but this is immediately succeeded by a syncline, and then an anticline arching over the occurrence of Amuri Limestone, with an E.-W. strike and a dip to the south on the upstream side. The overlying Mount Brown beds now come down to water level, but there is another small exposure of the bed about a chain further on. The bed therefore shows here an irregularity in dip and strike due to some slight deformational movement. From the point last mentioned it disappears from view.

The bed is really a calcareous greensand, becoming more sandy at higher levels. It is no doubt the local equivalent of the Weka Pass Stone, though it may grade up to the horizon of what is called the Grey Marl, itself definitely sandy and slightly glauconitic in places. It is important to note that it contains angular fragments of Amuri Limestone. They are most common near the base of the bed, but they also occur at higher levels. Their presence indicates a break with the Amuri Limestone. This may be local only, as the general evidence from other parts of the North Canterbury district appears to indicate conformity.

It may be noted that it contains "fucoids," and that its absence from the river section below the bridge may be explained in the same way as the absence of the Amuri Limestone from that locality.

The fault which bounds it on the north is associated with blocks of sandstone, fragments of Amuri Limestone and phosphatic nodules, which are in places no doubt reassorted.

Unconformity.—A stratigraphical break occurs at this stage.

7. *Hurunui Marl* and *Breccia* (see Sections Nos. 2 and 3).—This bed presents serious difficulties and the authors are still not entirely satisfied with the correctness of their interpretation, though it is given here as being the most reasonable in their opinion. The beds are typically developed on the south bank of the river in the lower part of the cliff face extending from the point for a distance of about 400 yards upstream. This is the least accessible part of the section, the river swirling round the base of steep cliffs. The beds consist of marls with lenses and masses of sandstone, and harder bands which contain fragments of either Amuri Limestone or Chalk Marl, probably of both, thus proving the existence of a break between the Hurunui Marl and the underlying beds. Associated with the marl is a breccia composed of fragments of Amuri Limestone, Chalk Marl, and Weka Pass Stone, and of another calcareous bed not seen anywhere in the locality. This last may be the equivalent of the Grey Marl or a higher part of the Weka Pass Stone, but it is not glauconitic and it is composed of fragments. The major fragments are of large size, some 25 feet in length, and frequently showing the effect of crushing. The marly facies is the bed marked 2 in Section No. 2 of our former paper (1928, p. 215), and correlated there with the Chalk Marl, which it closely resembles in places, but the presence of included fragments of Chalk Marl and Amuri Limestone rules that contention out. A similar marl occurs on the lagoon face, in a line with the Chalk Marl on the north bank below the bridge, and they were naturally taken to be identical, but the fragmentary nature of some of the bands appears to negative their identity. The occurrence on the south bank therefore appears to be connected with the marls just across the stream. All these beds lie flat or with slightly wavy inclination. The presence of large floater blocks themselves composed of smaller fragments implies that a consolidated bed occurred or still occurs covered up, between the top of the Amuri Limestone and the breccia just referred to. This may be the Grey Marl, which in this locality must be unconformable to the beds near the base of the section, seeing that the Weka Pass Stone, which underlies the Grey Marl, is itself unconformable to the Amuri Limestone and the Chalk Marl.

The relation of the large blocks to the finer marly facies is not clear, but they apparently underlie it and form the base of the bed. This can be seen near the point on the south side of the river. In our section just referred to (1928, p. 215) one of these blocks is represented as being faulted into the marl. This gives a correct representation of what appears, and the block may be pushed up, but this may not be due to faulting, and it may be attributable to

the settlement of weaker beds of marl around a more resistant solid mass. In any case the disturbance does not affect the overlying Mount Brown beds.

Just around the corner upstream from this point occurs a faulted mass of Amuri Limestone, with an accumulation of phosphatic nodules along the fault plane. This may have been faulted in position, in which case the fault does not reach the Mount Brown beds; in fact it cannot be detected passing through the large block formed of fragments which is associated with the Amuri Limestone block on the lower side of the fault plane. It is possible, too, that the faulting may date from the time anterior to the erosion which formed the block, that is, to the time when the beds they belonged to were still in position.

The question arises as to how such blocks may have been able to form a bed associated with a fine-grained marl. The answer to this is provided by the locality itself. From the face of the lagoon cliff large blocks are now being detached, falling down at the base of the cliff, perhaps transported a short distance by the waves, while round them accumulates a calcareous mud analogous to the marl. Similarly at the Napenape Limestone cliffs, about five miles south, large blocks of limestone are being embedded in marine deposits and, if the water were still or enclosed, deposits analogous to those at the Hurunui would be laid down. The deposit has been formed at the base of a cliff alongside the sea, and this cliff must have contained beds formed of Chalk Marl, Amuri Limestone, and the equivalent of the Weka Pass Stone and probably the Grey Marl, the evidence for unconformity being the lithological character of the included blocks. The strike and dip are so uncertain in places that it cannot be used as a criterion for conformity or otherwise. We have given the name Hurunui Marl and Breccia to this bed because of the uncertainty of its correlation with beds in other parts of the district. It may be equivalent to the Grey Marl, and in that case it would necessitate the placing of a break between the Grey Marl and the Weka Pass Stone in this particular locality and perhaps elsewhere, although the general consensus of opinion is that the Grey Marl and the Weka Pass Stone are conformable. All the same, both Haast and Park considered the relation to be unconformable. It should be noted that at the base of the cliff south of the river where the Chalk Marl and Hurunui Marl are in contact, it is difficult to say where the boundary lies. Beds without included fragments are assigned to the former, while those with fragments are placed with the latter. (See Section 2).

Unconformity.—This unconformity is the one which was discussed in our former paper, and the evidence given there is endorsed.

8. *Mount Brown Beds.*—These are as described formerly. They occur upstream on both sides of the river, form the main part of the cliffs south of the river, and a long stretch of the banks below the bridge on the north side of the stream, and also a part of the cliffs on the lagoon front. There are, however, one or two observations to be made.

The occurrence farthest upstream is developed on both sides of the river. The next occurrence following the stream down also lies across the river. In our former paper the contact of this bed and the Chalk Marl is represented as an erosion contact on the upstream side. Having examined both sides of the river, the most reasonable explanation of the junction of this bed with the marl is that it is a fault contact, with some overthrusting from the north-west. The Mount Brown beds can now be traced along the bank at river level for a considerable distance upstream beyond the point where it was seen by us previously, and the position renders it practically certain that the beds have been overthrust from the north-west. This is supported by the fact that the Mount Brown beds occur in a similar position on the north bank, and this increases the unlikelihood of an erosion contact on the upstream side of the occurrence. It is further increased by the observation that the Chalk Marl is exposed in a cutting on the road to the south of the river, where it would be reasonable to expect Mount Brown beds, were the contact an erosion contact. All the same the steep contacts which are clearly seen in other cases, and our explanation of the erosion along a sea-cliff to account for the inclusion of such large floater masses in the sand, support the possibility of the junction being an erosion contact. The crushing and faulting of the beds in close proximity upstream support the fault hypothesis, and therefore this is accepted as probable.

It must be noted, too, that our original section should be amended so as to show these beds at river level, although there is an isolated occurrence of Chalk Marl at river-level with Mount Brown beds both above and below it upstream and downstream from it. It should be noted that a talus slope has been swept from this point by river erosion since we last saw it.

The occurrence on the south bank downstream from the bridge does not need further comment beyond what was made in our former paper, except to note the very steep contact between the Mount Brown beds and the Chalk Marl on the face of the hill just opposite the end of the bridge. Also some obscure remains of fossils were found on the hillside just above the contact.

There remains the occurrence north of the river. About 400 yards downstream from the bridge these beds form the bank of the river, butting against the Chalk Marl, and acting as a mere fringe which continues down till just past the plantation on the reserve. The large size of the floating blocks is noteworthy. The Hurunui Marl then continues for nearly 70 yards, then the Mount Brown comes in for 14 yards, forming a point in the cliff. This is succeeded by 500 yards of Hurunui Marl, after which the Mount Brown beds continue round the cliff face for over 400 yards, capping in places first of all the Hurunui Marl and then the Weka Pass Greensand.

At one place, near the western end just opposite the end of the road, the contact is a fault, although the steepness of the line of junction elsewhere suggests that it too may be an erosion contact.

The fact that the marl overrides the Mount Brown beds is, however, strongly suggestive of a fault contact here. There is another fault on the north-east side of the point some 70 yards from the road, where the evidence is analogous to that in the first case.

It may be noted as well that the lower part of the Mount Brown beds consist of a sandstone usually free from large blocks; these come in at a higher level, and the final facies is one of pure sandstone without the large blocks.

There remains now the final question to consider as to what are the precise relations of the Mount Brown beds to the Hurunui Marls, for there are difficulties which have not been disclosed up to the present. These relate chiefly to the lower level of the Mount Brown beds on the north side of the river below the bridge as compared with the level of the top of the Hurunui Marls in the cliff south of the river. This might suggest that the Hurunui Marls were interstratified with the Mount Brown beds. As against this there is no such interstratification in the occurrence of Mount Brown beds above the bridge. Also, opposite the end of the bridge on the south bank the upper facies of Mount Brown beds rest directly on the Chalk Marl, although with a very steep contact. It is to be observed that the large blocks are more common in the Mount Brown beds on the north side of the river near the plantation, but they also occur on the south side of the river in a position definitely above the Hurunui Marls. For these reasons therefore we consider that the Hurunui Marls are not interstratified with the brown sandstones of the Mount Brown Series. That being so, there is the possibility of the lower level of the occurrence north of the river being due to a downthrow. Of this there is no definite evidence. The remaining explanation is that they have been laid down on a very irregular surface, and that under the river lie concealed either the entire Amuri Limestone beds and the Weka Pass Greensands, or such remnants as have escaped erosion.

9. The closing members of the sequence exposed near the mouth of the river consist of gravels and loose beds. The former cap the cliffs south of the river as a thick veneer, and they also occur on the terraces between the river bank and the slopes of Mount Seddon. The former are perhaps the Kowai Gravels, whereas the latter are in general the deposits of the river when it ran at higher levels, but in one case at least, near the northern end of the lagoon cliff, gravels are capped with loess, also containing thin layers of pebbles, and it is probable that in this case these gravels are pre-glacial, that is, belong to the Kowai Series.

It will be seen from this description that the area furnishes evidence of three unconformities in the Tertiary sequence:—

(1) Between (a) the Weka Pass Greensand and Grey Marl, and (b) the Amuri Limestone.

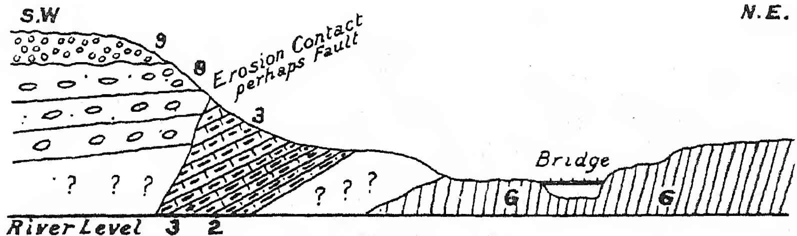
(2) Between (a) the Hurunui Marl, and (b) the Weka Pass Greensand and Grey Marl, and therefore also with the Amuri Limestone.

(3) Between (a) the Mount Brown beds, and (b) the Hurunui Marl and lower beds.

The question of the conformity or otherwise of the Greta Marl and the Mount Brown beds does not arise.

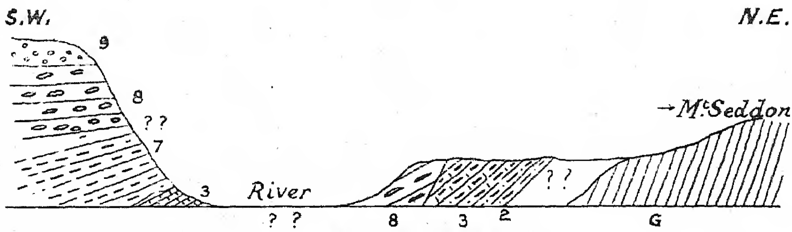
In deciding on these unconformities no assistance has been received from the fossil content of the beds, since the only place where fossils were discovered was in the Mount Brown beds just opposite the southern end of the bridge.

The last of the three unconformities mentioned above is believed to be widespread, but it is questionable whether the unconformity is only local in the cases of Nos. 1 and 2. The possibility of local unconformity with general conformity can be illustrated from the district, for deposition may be continuous in the bed of the sea off the coast, whereas near the cliffs erosion may be proceeding as local uplift or warping brings a part of the beds concerned within the sphere of action of the waves. These are the circumstances under which fragments of large size may form locally a dominant element in a bed. The bed may pass gradually into a fine-grained sandstone or marl with parallel stratification and without a distinct break offshore, if the elevation has been restricted to a narrow coastal belt and has petered out either suddenly or gradually when traced seaward. This appears to be perfectly possible at Hurunui.



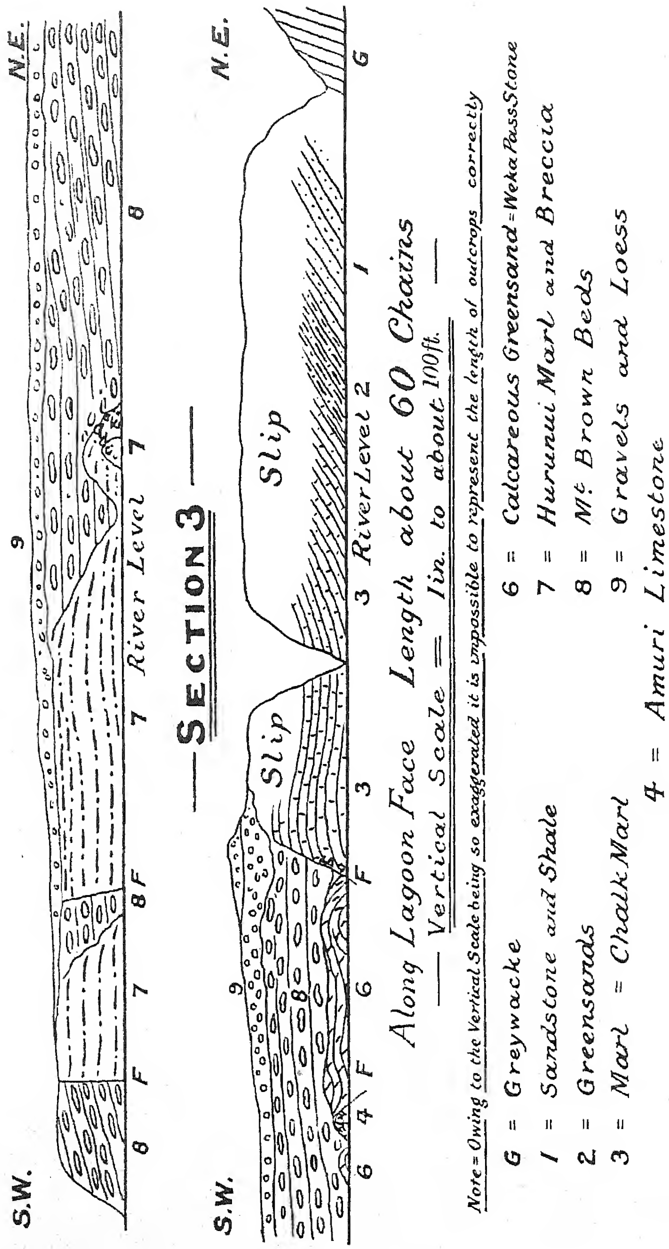
SECTION I

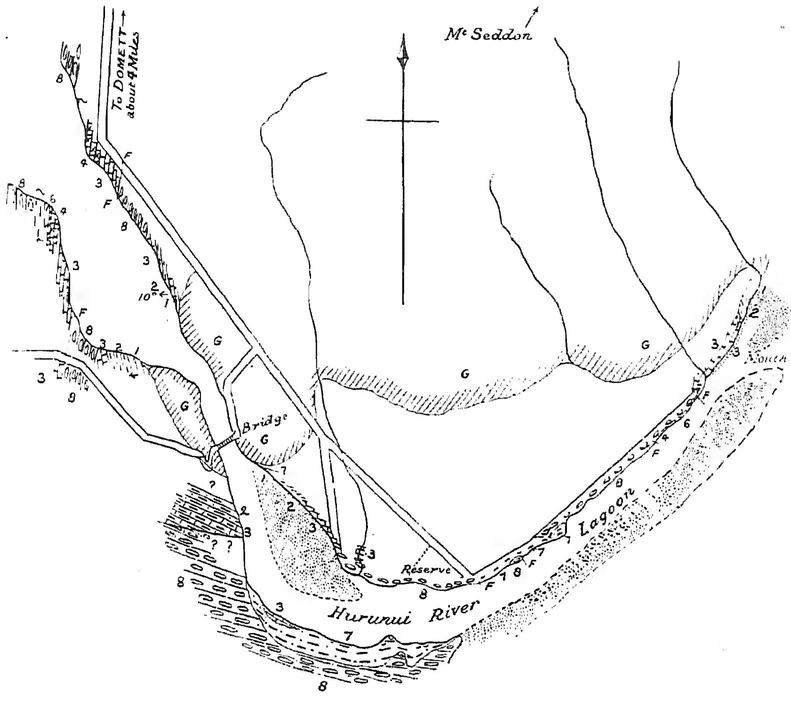
Across Bridge-Length about 15 Chains



SECTION 2

Across River 20 Chains below Bridge – Length 30 Chains


S.W.
N.E.
8
F
7
8F
7
River Level
7
8
9
— Section 3 —
S.W.
N.E.
6
4
F
6
F
3
3
River Level 2
1
G
9
8
Slip
Slip
Along Lagoon Face Length about 60 Chains
— Vertical Scale = 1in. to about 100ft. —
Note = Owing to the Vertical Scale being so exaggerated it is impossible to represent the length of outcrops correctly
G = Greywacke
1 = Sandstone and Shale
2 = Greensands
3 = Marl = Chalk Marl
4 = Amuri Limestone
6 = Calcareous Greensand = Weka Pass Stone
7 = Hurunui Marl and Breccia
8 = Mt Brown Beds
9 = Gravels and Loess



GEOLOGICAL SKETCH MAP OF HURUNUI MOUTH

Scale of Chains

10 5 0 10 20 30

G. = *Greywacke*	4 = *Amuri Limestone*
1 = *Sandstone & Shale*	6 = *Calcareous Greensand (Weka Pass Stone)*
2 = *Greensands*	7 = *Hurunui Marl & Breccia*
3 = *Marl = Chalk Marl*	8 = *Mt Brown Beds*

OBITUARY NOTICES.

Mr Alfred Philpott, F.E.S.

Mr Alfred Philpott, F.E.S., whose death occurred in Auckland on July 24 last, was one of the best known entomologists in New Zealand. Born in Invercargill in 1871, he early showed a keen interest in natural history, and more particularly in insects. During the earlier part of his life he was engaged in commercial pursuits, but found time to make a fine collection of all kinds of New Zealand insects, though he was chiefly interested in the Order Lepidoptera. He was also for some years Curator of the Southland Museum.

MR ALFRED PHILPOTT, F.E.S.

During my first visit to New Zealand, in 1919, I made the personal acquaintance of Mr Philpott, with whom I had corresponded for some years previously. We spent some days together at Queenstown and climbed Ben Lomond, and I realised at once that my new acquaintance was a born entomologist and a keen lover of nature. Later, when I was invited to take the post of Chief of the Biological Department of the newly-formed Cawthron Institute, at Nelson, I selected Philpott as the ideal man to fill the post of Assistant Entomo-

logist, and strongly recommended him for that post. He accepted the offer of the Cawthron Trustees, and started work in Nelson while I was away travelling in America and Europe. On my return in December, 1920, I found him hard at work laying the foundations of the fine collections there, and generally helping to build up the new Department. Though he was naturally not interested in economic problems as such, but only in pure science, he threw himself heartily into all the new lines of economic entomology which were then being started. I think one of the greatest claims he has on the affectionate remembrance of New Zealanders lies in the extraordinarily careful and painstaking way in which he carried out the difficult details of the work of acclimatising *Aphelinus mali*, the parasite of Woolly Aphis, which I had introduced from America. There was a time, in September, 1921, when, but for Philpott's unremitting care, this first brood of *Aphelinus*, reduced by the severe winter to only about three pairs, would otherwise have entirely perished, thus entailing the cost and trouble of introducing a fresh strain, with all its attendant delays and uncertainties. But he succeeded in bringing the remnant safely through, and the millions of these parasites which now aid in controlling the woolly aphis throughout New Zealand and Australia are all the progeny of the very few that he saved in those anxious days.

As long as he continued in his post of Assistant Entomologist, Philpott carried out all his duties with the most unfailing regularity and care. I can truthfully say that I have never known a more reliable worker. But his heart was always in pure science; and when, in 1923, his private fortune enabled him to become independent, he asked permission to be allowed to continue work on his favourite Order Lepidoptera, without official salary. His resignation from the post of Assistant Entomologist was accepted by the Trustees with regret, and he was appointed Honorary Lepidopterist. This post he held until June, 1929, when the occurrence of the great earthquake in Nelson Province was the immediate occasion of his removal to Auckland and of the severance of his connection with the Cawthron Institute. During the six years in which he was Honorary Lepidopterist, he built up an extremely fine collection of New Zealand Lepidoptera, basing it on his own original collection, which he most generously presented to the Cawthron Institute. He also worked away so strenuously at the systematics and morphology of New Zealand Lepidoptera, that he published a long series of valuable papers, in which a considerable number of new species were described, various obscure organs were detected and discussed, and the difficult problem of the evolution of the genitalia in various groups was worked out with great thoroughness. This work brought him into contact with other workers all over the world, so that, at the time of his death, he had gained a reputation second to none in New Zealand for reliable and painstaking work in pure entomology.

On leaving Nelson he became Honorary Entomologist to the Auckland Museum, a post which he held at the time of his death.

Philpott published in all no less than seventy-three scientific papers, chiefly on the Lepidoptera, but some on other Orders of Insects and one or two on Birds.

Besides being a fine entomologist, Philpott was a writer of rare literary style, being in the direct succession of the famous essayists and a true disciple of "Elia." For many years he wrote regularly the leading article in the Saturday "Nelson Evening Mail." These articles, mostly dealing with literary subjects, were looked forward to by a wide circle of readers and were highly appreciated by the more discerning. I have often thought that they might have an even wider appeal if collected together and published in one volume.

Other useful activities carried on by Philpott during his life in Nelson were connected with the Literary Institute and Philosophical Society; he served for years on the Committee of the former and as Secretary of the latter. He was also a keen and ardent bushman and explorer, and had traversed little-known regions both in Southland and Nelson Provinces.

Philpott's outstanding characteristics were his imperturbable good nature and his generosity of thought and action. Though he was a convinced rationalist and basically opposed to all organised religion, he set an example of high moral conduct which I have seldom known equalled. In a letter written to me only a month before he died, when he had hopes of an ultimate recovery, he spoke of his ardent desire to continue for ten more years working at his beloved subject, so that he might leave the systematics of the Lepidoptera "on a sound and structural basis." This hope, alas, was not destined to be fulfilled, but it may stand as a monument to the high ideals which informed all his actions, and as a clear indication of his firm belief that man's whole duty was to build well some small portion of the great Temple of Knowledge, which might for ever serve to aid humanity in its onward progressive march.

Canberra, Australia, R. J. TILLYARD.

Joseph Crosby-Smith, 1853-1930.

CROSBY-SMITH was one of that honourable band of self-educated naturalists which has played a distinguished part in investigating the natural history of the British Empire. He was born at Keighley, Yorkshire, on July 18, 1853. At the age of nine—but only during part of the day—he was employed at the Dean Clough carpet mill. One of the partners, Mr Edward Crowley, had a private observatory which the boy was encouraged to visit, and there, under the stimulus of the astronomical observer, his latent taste for natural science seems to have been awakened.

At the age of twenty-three, accompanied by his wife, he emigrated to New Zealand, and settled down in Dunedin, where for 25 years he was employed as bookkeeper at the foundry of H. E. Shacklock. In 1879, Crosby-Smith became teacher of shorthand at the newly-

established evening classes of the Caledonian Society, and proved a most successful teacher. During the years which followed, until he was elected a member of the Otago Institute in 1896 (President, 1926), very little is on record regarding his activities as a naturalist, but it is highly probable that he had earlier made the acquaintance of Messrs G. M. Thomson and D. Petrie, and so acquired an elementary knowledge of a good many species belonging to the local florula. Towards the close of the 'nineties—but it may have been earlier—Crosby-Smith became an active member of that excellent body, the Otago Field Naturalists' Club, and he devoted a good deal of his spare time to the study of seaweeds, much of his material being sent to Mr R. M. Laing for identification. He also extended considerably his knowledge of the ferns, the fern allies, and the seed plants.

JOSEPH CROSBY-SMITH, 1853, 1930.

In 1902, having resigned his Dunedin position, he removed to Invercargill and established the ironmongery firm of Smith and Laing, residing in that city till 1925. During that period Crosby-Smith greatly broadened the scheme of his botanical work, especially in the direction of botanising unknown areas, of botanical photography, and eventually of publishing original papers. His most important botanical excursions were to the following places:—The Princess Ranges; the Takitimu Mountains (with D. Petrie); the

Longwood Range (with myself); Mount Anglem, Stewart Island (with F. G. Gibbs, R. M. Laing, and myself); the Clinton Valley and McKinnon's Pass (with myself); Campbell Islands (as a member of the Sub-Antarctic Islands Expedition of 1927); and many but little-known localities on the Southland Plains. His most important publications deal with the flora of the Lake Hauroko area (previously quite unknown, and entailing much hard physical work), a list of the phanerogams of Southland (most useful but rather premature), and a valuable short paper detailing the occurrence of high mountain species at sea-level in Southland. Apart from these technical publications, Crosby-Smith performed the eminently useful role of popularising his beloved science by means of newspaper articles, popular lectures (illustrated by his coloured lantern slides, which he presented to the New Zealand Institute), and instruction to those, not few in number, who sought his advice.

As a public man, apart from his invaluable influence as explained above, he was for many years a member of the Southland Education Board, and for some time its chairman. He also took part in all movements which were for the betterment and uplifting of the people.

I have had the privilege of Crosby-Smith's intimate acquaintance for about 26 years. Would that my tribute to his memory were more worthy. He was a delightful companion—his Yorkshire humour always to the fore—a true lover of Nature. Can I say much more in a man's honour—a loyal generous friend and a perfect Christian gentleman, full of loving kindness. Nor in speaking of the man must I neglect the devoted wife, his true comrade, to whom he owed so much.

In conclusion, let me say that during the past 44 years, though I have been closely connected with all the naturalists of this country, there is not one for whom I feel a deeper respect than my old friend, the subject of this brief notice, which it has been my sorrowful duty to contribute to those "Transactions" which he so highly valued.

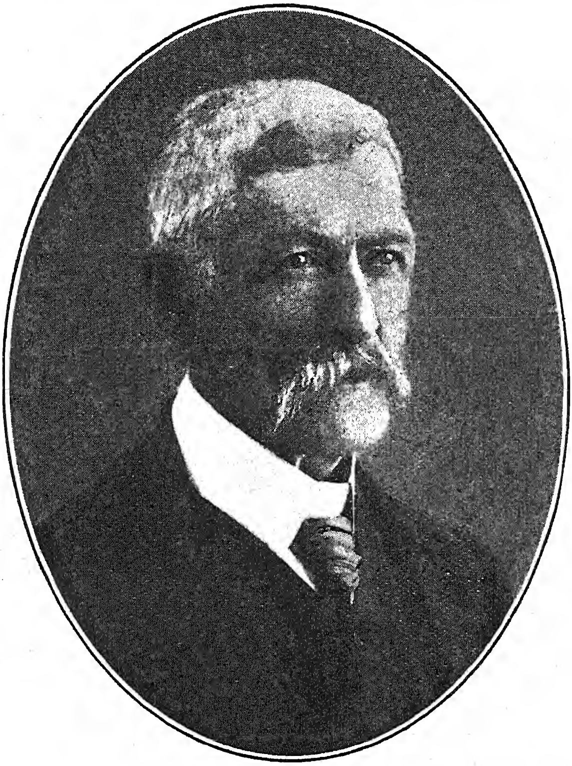
L. C.

Harry Carse, 1857-1930.

The death of Harry Carse, which occurred on November 25th, 1930, has removed from our midst one of the few remaining members of the old school of taxonomic botanists whose labours have done so much to place New Zealand botany on a secure foundation.

Carse was born at Leek, a small town in Staffordshire, his parents being of Scottish descent. Most of his early education was received at Musselburgh, near the Firth of Forth, within easy reach of Edinburgh, and after he left school he took up a position in Macclesfield Bank, of which his father was manager. After he had spent some years at banking work, the call of the new lands across the seas became too strong to be resisted and he embarked on the s.s. Kaikoura and set foot in this country in 1885.

For some time, a stranger in a strange land, he had to take up whatever work was available, but before long he came into contact with R. J. O'Sullivan, Inspector of Schools under the Auckland Education Board, who recognised him as one whose education and personal qualities fitted him for more important work than that in which he was engaged, and he was given the post of assistant teacher at the Newton West School. His next position was that of relieving teacher at Helensville, and later he was sent to Chelsea to open a school newly-established in that district. From that time onwards



HARRY CARSE, 1857, 1930.

for over thirty years he served under the Auckland Education Board at Hunua, Kaitaia, Mauku, Kaiaka, and Maungatapere. The only break in his long period of teaching service was a space of two years, when he resigned and engaged in dairy farming at Kaiaka. Later, he took the post of teacher at the Kaiaka School, and after his resignation a few years later he came to Auckland to retire, and lived successively at New Lynn and One Tree Hill.

Always a lover of Nature, Carse found ample scope for his studies in the various parts of the Auckland district in which he was stationed, and he was much encouraged by Petrie, who as Inspector of Schools, regularly came into contact with him and rendered him much assistance. It is not surprising, therefore, that Carse developed

into a taxonomic botanist, the class to which Petrie himself belonged. He was chiefly concerned in collecting and cataloguing plants and in the making of an herbarium, and paid less attention to their activity as living organisms or to their relations with their environment. In this field of botanical study Carse did a great deal of extremely valuable work and added many species to the flora. His most outstanding work was done among the Filices and the Cyperaceae. Most of his collecting work was done in the Auckland Province, but he also collected in the Tongariro National Park, and in other localities farther south. He exchanged freely with local and southern botanists, and was also in constant communication with overseas pteridologists, especially Christensen, of Copenhagen. His papers, most of which appear in the *Transactions* of the New Zealand Institute, are mainly descriptive of new plants which by his keen observation and painstaking diagnosis he had added to the flora. His enthusiasm knew no bounds, and at every opportunity he was out in the field with his simple but effective collecting apparatus in search of new treasures to add to his herbarium. The latter, while not so large or so comprehensive as those of Cheeseman and Petrie, is an extremely interesting and valuable one, well-arranged and catalogued, and the Canterbury Museum, to which he left it, has been indeed fortunate in securing a collection so valuable. During his lifetime he presented a considerable number of specimens to the herbarium of the Auckland University College.

His achievements in the domain of New Zealand field botany will be more greatly appreciated when it is remembered that he was largely self-taught, having acquired his fund of botanical knowledge by wide reading and unceasing study and observation in the field. As regards his personal qualities, those who were fortunate enough to be his friends can have but one opinion. He was a gentleman in the highest connotation of that term, and will be much missed by those who have known his kindly and genial nature and his readiness to help all who came to him in difficulty.

T. L. LANCASTER.

TRANSACTIONS

AND

PROCEEDINGS

OF THE

NEW ZEALAND INSTITUTE

VOL. 62

(Quarterly Issue)

Parts 3 and 4, MARCH, 1932

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NEW ZEALAND INSTITUTE

1931

ANNUAL MEETING OF THE BOARD OF GOVERNORS, 20th MAY, 1931.

THE Annual Meeting of the Board of Governors was held in the Biology Lecture Hall, Victoria University College, Wellington, on Wednesday, 20th May, 1931, at 10 a.m.

Present: Representing the Government—Dr E. Marsden, Messrs B. C. Aston, and W. R. B. Oliver; representing Auckland Institute—Professors Segar and Worley; representing Wellington Philosophical Society—Professor Kirk and Mr G. V. Hudson; representing Philosophical Institute of Canterbury—Dr C. Coleridge Farr and Professor Speight; representing Otago Institute—Hon. G. M. Thomson and Professor Park; representing Nelson Institute—Professor Easterfield; representing Manawatu Philosophical Society—Mr M. A. Eliott; representing Hawke's Bay Philosophical Institute—Mr C. F. H. Pollock.

Dr C. Coleridge Farr presided and welcomed Professor R. Speight and Mr C. F. H. Pollock, two new members of the Board of Governors.

Apologies were received from His Excellency the Governor-General, the Rt. Hon. the Prime Minister, and Dr L. Cockayne, C.M.G.

Presidential Address: In commencing his address, Dr Farr asked members to rise in respect to the memory of the late Mr A. M. Wright, who had died very suddenly on the evening after the last Annual Meeting, which he had attended; of the late Mr Carse, of Auckland, Mr Alfred Philpott, Mr Crosby-Smith, Mr F. T. Leighton, Sir Robert Stout, all members of the Institute, and of Lady Hector. He referred also to the death of Sir W. T. Thistelton-Dyer, an honorary member of the Institute; and to Lord Melchett, the mainspring of Imperial Chemical Industries. At the conclusion of his address, Dr Farr was heartily thanked, and was asked to allow his address to be printed.

Notices of Motion were then called for.

Fellowship Election: The election for two vacancies in the Fellowship was then taken, and on receiving the result from the Hon. Returning Officer (Professor Segar), the President announced that

Dr E. Kidson was elected and that three others tied for second place. A second ballot resulted in Dr D. Miller being elected. Dr E. Kidson and Dr D. Miller were therefore announced duly elected to the Fellowship.

Hector Award: The President then opened the sealed envelope containing the report of the Hector Award Committee as follows:—

"The Committee has considered the claims of the New Zealand chemists in connection with the award of the Hector Medal and Prize for 1931. The Committee is unanimously of the opinion that the medal should be awarded to Dr W. P. Evans, who through many years of study of the New Zealand coals in their chemical, physical, botanical, and geological relationship, and through the stimulating influence he has exerted upon a large number of chemical students, has done so much to advance the science of Chemistry in New Zealand."

(Signed) B. C. Aston (Convener).
P. W. Robertson.
Thomas H. Easterfield.

The report was adopted.

Amount of Hector Award: On the motion of Mr Eliott, seconded by Professor Park, it was resolved that the amount of the Hector Prize be £60.

Declaration of Vacancies in Honorary Members' List: One vacancy occasioned by the death of Sir W. T. Thistelton-Dyer was declared.

Incorporated Societies' Reports and Balance Sheets: With the exception of the report and balance sheet of Manawatu Philosophical Society, and the report of Hawke's Bay Philosophical Institute, the reports and balance sheets of all incorporated societies were laid on the table and were referred to the Hon. Treasurer for report. It was explained that the balance sheet of the Hawke's Bay Philosophical Institute had been recovered, but the report had been destroyed in the recent earthquake and fire in Napier.

REPORT OF THE STANDING COMMITTEE FOR THE PERIOD ENDED 31ST MARCH, 1931.

Meetings: Eight meetings of the Standing Committee were held during the period under review, the attendance being as follows:—Dr Farr (President), Christchurch, 6; Mr Aston, Wellington, 8; Dr Cockayne, Ngaio, 5; Mr Eliott, Palmerston North, 4; Mr Hudson, Wellington, 8; Professor Kirk, Wellington, 4; Dr Marsden, Wellington, 5; Mr Oliver, Wellington, 7; Hon. G. M. Thomson, Dunedin, 1.

The Late Mr A. M. Wright: News of the death of the late Mr A. M. Wright two days after the last Annual Meeting, which he attended, came as a great shock to members. At a meeting of the Standing Committee in February the following resolution was carried:—

"That this meeting learns with great regret of the sudden death of Mr A. M. Wright, F.I.C., and desires to place on record its sense of the valuable work he did in the interests of the New Zealand Institute, and the chemical investigation of problems associated with the frozen meat industry of this Dominion."

A copy of this resolution was forwarded to Mrs Wright, and it was also published in the press.

Board of Governors: The vacancy on the Board created by the death of Mr Wright was filled, in May, by the appointment of Professor R. Speight, of Christchurch, who with Dr Farr now represents the Philosophical Institute of Canterbury.

A further change in the personnel of the Board occurred in May, when Mr C. F. H. Pollock was appointed to represent the Hawke's Bay Philosophical Institute in place of Mr Guthrie Smith, who had resigned.

New Zealand Institute Act: In February, a committee consisting of Messrs Oliver (convener), Aston, Hudson, and Dr Cockayne, was set up to draw up the necessary amendments to the New Zealand Institute Act and to inquire into the procedure necessary to obtain permission to include the word "Royal" in the title of the New Zealand Institute.

The Amending Bill which was eventually drawn up provided for the appointment of a vice-president, for the financial year to end on the 31st March instead of 31st December, and for the Annual Meeting to be held in April or May. It also transferred the administration of the Institute Act from the Department of Internal Affairs to the Department of Scientific and Industrial Research, the Rt. Hon. the Prime Minister, as Minister of the Department, automatically replacing the Hon. Minister of Internal Affairs on the Board of Governors.

Further the following paragraph was added to the Act:—"One additional member may from time to time be appointed by the Board for a term not exceeding two years, save that any such member may, on the expiration of his term of office, be reappointed as a member of the Board."

The Amending Act was passed by Parliament in October, 1930. The Department of Internal Affairs was subsequently written to and assured of the Institute's appreciation of its services to the Institute during the many years of its association with it.

Vice-President: Following the passing of the Amendment Act, the Standing Committee at its meeting on the 4th November, unanimously resolved that Mr B. C. Aston be appointed Vice-President of the Institute. The President, Dr Farr, mentioned that apparently it was the considered opinion of all members that Mr Aston by virtue of his long and intimate administrative association with the Institute was eminently suited for the position of Vice-President. Mr Aston replying, thanked the members for their confidence in him.

Publication Matters: The last part of Volume 60 was published in April. Acting on an instruction of the Finance Committee set up at last Annual Meeting, the size of Volume 61 was restricted in order that its cost might come within the means of the Institute. This necessitated the last part being a combined Part 3 and 4. Part 1 was published in June, Part 2 in September, and Part 3 and 4 in January last. The contract with Messrs Ferguson and Osborn, Ltd., having expired, and the Government Printer having expressed the desire to again undertake the printing of the *Transactions* and stating that he would now be prepared to tender for the work, it was decided to call for tenders from all suitable printers, and this was done on the 6th March, 1931. The tenders received have not yet been considered by the Standing Committee. In the meantime Volume 62 is not being proceeded with.

Exchange List: The Timaru Public Library and the Natural History Society, Riga, were added to the Exchange List.

Partial Sets Transactions: A partial set of the *Transactions* was donated to the Turanganui Public Library, Gisborne, and a few odd numbers to the Dominion Museum. An unbound set of Maori Art was also presented to Victoria University College Library.

Sales: The revenue of the Institute has been increased to the amount of £87 by sales of publications, an increase of over £20 on the previous year.

Library: There is very great congestion in the Library, the incoming exchanges having used up all the available space. It is difficult to know just how the steady influx of periodicals can be accommodated until such time as the new Museum buildings are available.

The Library continues to be used by research workers and is being more and more used by honours students of the College.

Incorporated Societies: The following reports and balance sheets of incorporated societies have been received and are now laid on the table:—

Auckland Institute for the year ended 31st March, 1930.
Wellington Philosophical Society for the year ended 31st October, 1930.
Philosophical Institute of Canterbury for the year ended 31st October, 1930.
Otago Institute for the year ended 30th November, 1930.
Nelson Philosophical Society for the year ended 30th September, 1930.

Owing to the upheaval in Napier, the report of the Hawke's Bay Philosophical Institute is not yet ready; the report of the Manawatu Philosophical Society is also not yet available.

A suggestion emanating from the Wellington Philosophical Society that the incorporated societies should be known as local branches of the New Zealand Institute was in November referred to the other incorporated societies for consideration. The replies of the societies were read at a meeting of the Standing Committee held on the 20th January, 1931, and were referred to the Annual Meeting.

Institute of Chemistry: A New Zealand Institute of Chemistry has been formed, and it was considered by the Standing Committee that it would be of mutual advantage if the newly-formed Institute became affiliated with the New Zealand Institute. On the 20th January, Mr Aston reported that he had discussed the matter with the Institute of Chemistry, and the suggestion would be considered later on.

Fellowship N.Z. Institute: On the 20th March, Professor William Percival Evans, M.A., Ph.D., and Mr Alfred Philpott, F.E.S., were gazetted Fellows of the New Zealand Institute.

Ten nominations were received from incorporated societies for the 1931 Fellowship and were submitted to the Fellows for selection. The result of the selection was notified by the Hon. Returning Officer (Professor Segar) on the 18th September, and later reported to the members of the Board of Governors.

A letter was received from the Philosophical Institute of Canterbury on the 28th June expressing dissatisfaction with the present method of electing Fellows, but no action was taken, as at last Annual Meeting a committee was set up to report to the next Annual Meeting on the method of electing Fellows of the New Zealand Institute. This committee drew up certain recommendations which will be submitted to the Annual Meeting in May.

Hector Award: At a largely attended meeting of the Otago Institute held on the 6th July, the President of the New Zealand Institute, Dr C. Coleridge Farr, presented the Hector Medal to the Rev. Dr J. E. Holloway, and spoke in high terms of Dr Holloway's botanical work, which is held in high esteem not only throughout New Zealand, but also in the outside botanical world.

National Research Council: At a meeting of the Standing Committee held on the 20th February, it was resolved that a committee consisting of the President, the Hon. G. M. Thomson, Mr Oliver (convener), and Dr Marsden, be set up to report on the proposed National Research Council on the lines set down at last Annual Meeting of the Board. The report of this committee will be submitted to the Annual Meeting in May.

Research Grants: On the 4th November, the Standing Committee considered the recommendations of the Research Grants Committee and approved of eight applications for research grants.

Research Grant Policy: It was felt that the New Zealand Institute should follow a definite policy in dealing with applications for research grants, and it was decided to ask the Research Grants Committee to furnish a report on the matter. This report was considered at a meeting of the Standing Committee in May, when it was decided that it be circulated to members of the Board so that the matter might come up for discussion at the Annual Meeting. However, intimation has now been received from the Department of Scientific and Industrial Research that there will be no provision on the Estimates for 1931 for research grants for the New Zealand Institute, and consideration of a research grant policy is at present unnecessary.

Carter Bequest: A meeting of the Carter Bequest Committee consisting of Professor Kirk (convener), Dr Farr, Mr Aston, and Mr Hudson, was held on the 3rd April, 1930. Dr Adams was present by invitation.

It was decided to ask the Crown Law Office to draft a Bill to give effect to the decision of the Board of Governors in January, 1929, but before approaching the Crown Law Office, to inform the City Council of the Institute's intention and ask whether, when an Act was obtained, the Council would transfer to the Institute as Carter Observatory Trustees a site of one quarter of an acre in the position already agreed upon and would donate the telescope or sell it to the Trustees at a price not exceeding £500.

A letter to this effect was written to the Mayor of Wellington on the 3rd April, a copy of the letter being sent to the New Zealand Astronomical Society. On the 17th April, the Town Clerk replied that the letter would be placed before the Observatory Committee at an early date. On the 3rd November, the Town Clerk informed the Institute that the recommendations of the Observatory Committee and the Reserves Committee on the matter were reported to the Council, but consideration of same had been deferred pending a report from the City Engineer regarding a proposed road adjoining the site in question.

Science Congress, 1931: The Standing Committee was empowered by last Annual Meeting to inquire into the possibility of the next Science Congress being held in Napier. In July, the Hawke's Bay Philosophical Institute wrote regretting that it was unable to undertake the organisation of the Science Congress. No further action was taken.

T. K. Sidey Summer Time Fund: In April, Dr Cockayne and Professor Kirk were asked to suggest a design for the proposed Summer Time Medal. They suggested that the obverse side should bear the donor in profile, and that on the reverse side the design should represent the sun's rays from above with the sun's disc or portion of it, while below on each side should be representations of Demeter and Hygeia. These suggestions were approved by members of the Standing Committee and by Sir Thomas Sidey, and instructions were accordingly sent to Mr A. G. Wyon on the 5th May. On the 7th August the design for the medal was received from Mr Wyon, and with a slight alteration was approved at a meeting of the Standing Committee held on the 24th September. Mr Wyon undertook to have the medals ready by May.

Sir Thomas Sidey, in fulfilment of his promise to donate the medal, forwarded his cheque for £120 to cover the cost of it.

The committee set up at last Annual Meeting to revise one of the Regulations affecting the Summer Time Award, reports as follows:—

> "I have to report that it has been impossible to obtain a full meeting of the Committee; but I have communicated with the members by correspondence, and find that there is considerable difference of opinion as to whether or not applications for the award shall be called by public advertisement."

As a compromise I suggest the following regulation:—

> "Applications for the award shall be called by public advertisement, and applicants shall be invited to submit a thesis specially prepared on the subject of the award, or the applicants may submit papers already published. The Board shall elect a Committee of not less than three experts to make recommendations regarding the award, and where the subject has a medical bearing, expert medical opinion on the value of the thesis or publications shall be obtained. In making the award, however, the Board shall not be limited to persons who have made application."

(Signed) E. MARSDEN,
Convener Sidey Medal Committee.

Dominion Museum: On the 2nd April, a deputation of members of the Standing Committee and others waited upon the Hon. Minister of Internal Affairs to protest against the proposed site on Mount Cook, and also against the proposed allocation of funds in the building of the Dominion Museum and National Art Gallery It was pointed out that it was an integral part of the

proposals under which the Massey Government agreed to grant a subsidy not exceeding £100,000 that the amount available for the Dominion Museum should be £150,000 out of a total of £200,000.

The Minister promised to re-submit the matter to Cabinet. The winning designs for the Dominion Museum and National Art Gallery buildings were announced on the 18th June, and subsequently Mr Oliver intimated that ample provision appeared to be made in the plans for the New Zealand Institute Library. The main room was nearly twice the size of the room in which the Library is now housed, and additional smaller rooms could be found as stack rooms.

Board of Trustees: The New Zealand Institute had no representation on the temporary Board of Trustees, and when it was announced that a permanent Board was to be set up, the Standing Committee resolved to again approach the Chairman of the Board and ask that the Institute might have at least two representatives on the Board. When the Bill eventually came down, it provided only for the inclusion of the President of the Institute as representative. It was resolved to leave the matter in the hands of the Hon. G. M. Thomson, with the result that when the Bill came before the Legislative Council it was amended, and the Act now provides for the President and Vice-President to represent the Institute on the Board, with power to appoint a deputy if necessary to attend meetings of the Board. At a meeting of the Standing Committee on the 4th November, Professor Kirk was appointed to act as deputy when necessary.

London Agency: It was resolved to approach the High Commissioner for New Zealand on the possibility of his office undertaking the agency for the Institute's publications. Later, Dr Marsden was asked to interview the High Commissioner and endeavour to arrange terms. On his return from England, Dr Marsden reported that it was probable that the High Commissioner would undertake the agency without commission charges, and the Prime Minister has now written to him asking him to do this.

Solar Eclipse: The Institute granted £100 from the Research Vote to Dr Adams for his expedition to Niuafou to view the solar eclipse.

Former Honorary Editor: The President of the Wellington Philosophical Society was asked to make a presentation of a cheque for £21 (contributions from the incorporated societies and from members of the Standing Committee) to Mr J. C. Andersen, in recognition of his services as Honorary Editor, and this was done by Mr Oliver at a meeting of the Wellington Philosophical Society held on the 21st May, 1930.

British Association for the Advancement of Science: Shortly after his arrival in New Zealand, His Excellency the Governor-General invited the British Association to meet in New Zealand in 1934. The President of the Institute wrote assuring His Excellency of the cordial support of the New Zealand Institute in the proposal. In replying, His Excellency said that acceptance of the invitation depended upon a similar invitation being sent from Australia and upon the necessary financial assistance being forthcoming from the New Zealand Government. Subsequently, it was ascertained from leading scientific men in Australia that owing to the extremely difficult financial conditions prevailing there, it was considered quite impracticable to ask the Government to issue an invitation to the British Association. The idea, therefore, unfortunately has had to be abandoned.

The British Association's Centenary takes place on September 23-30, 1931, and the New Zealand Institute has been invited to send a delegate. The appointment of a delegate was considered at a meeting of the Standing Committee held on the 4th November, and it was decided to defer appointment until the Annual Meeting.

Second International Polar Year: The International Meteorological Conference held at Copenhagen in 1929 decided to organise a second international polar year in 1932-33. At Dr Kidson's suggestion it was agreed that in the absence of a National Research Council, the New Zealand Institute could most suitably undertake the organisation of the Dominion's share in the proposed Polar Year. The following committee was therefore appointed with power to add:—His Excellency the Governor-General; Dr C. Coleridge Farr; Dr E. Marsden; G. Shirtcliffe, Esq.; W. R. B. Oliver, Esq.; Professor P. W. Burbridge;

H. E. Walsh, Esq.; Dr E. Kidson (convener); Sir Joseph Kinsey; Senior Naval Officer; Hon. Minister of Scientific and Industrial Research; Hon. G. M. Thomson; A. E. Hefford, Esq.; Professor W. N. Benson; Professor D. M. Y. Sommerville; and Professor D. C. H. Florance.

The Minister of Scientific and Industrial Research wrote regretting that it was not practicable for him to accept a seat on the Committee, as in his capacity of Prime Minister he would probably have to give consideration to the matter when approached by the Netherlands Foreign Office.

Correspondence in connection with the proposal has been circulated to members of the above committee and to interested bodies.

Scenery Preservation Committee: At last Annual Meeting a committee consisting of Dr Cockayne (convener), Messrs Aston, Hudson, and Oliver was set up to deal with matters of scenery preservation. This committee has been called together several times since then. Early in the year it was asked by the Department of Internal Affairs to report on the matter of the preservation of Maori rock paintings at Weka Pass, Canterbury. The recommendations of the committee were approved at a meeting of the Standing Committee on the 2nd April, 1930, and were to the effect that the suggestions submitted to the Department by Mr Oliver for the restoration of the paintings should be carried out, and that the Lands Department be asked to declare Weka Pass a scenic reserve. Further, that the Lands Department be urged to appoint an inspector of scenic reserves, and urge that the Scenic Reserves Act be amended. It was considered later, however, in view of the financial stringency, that the present time would be a most inopportune one to approach the Government in regard to the latter recommendation, and it was decided to leave the matter in abeyance for the present.

On the 4th November, Mr Oliver reported that protective measures had been carried out at Weka Pass and many of the rock paintings had been restored. The Lands Department also wrote that the Scenery Preservation Board had approved of the Institute's recommendation that Weka Pass be declared a scenic reserve, but a certain amount of compensation would be required, and funds at the present time were extremely limited, and it had therefore been decided to allow the matter to stand over for the present.

The reported destruction of Pittosporum Dallii at Boulder Lake, and the destruction of native bush at Puketitiri, notified by Hawke's Bay Philosophical Institute, were matters that were also dealt with.

On the 25th February, 1931, it was reported that much unnecessary felling of trees was occurring at Tongariro National Park and in other places, and notice had recently been drawn to the destruction by Public Works men of a tree sacred to the Maori. It was resolved that Mr Aston, Dr Cockayne, and Mr Field, M.P., should interview Mr Furkert, Chief of the Public Works, and take any action that was necessary.

A conference, organised by the Department of Internal Affairs, of interested bodies to discuss the question of deer control, was attended by Messrs J. Scott Thomson and Mr E. F. Stead as representatives of the New Zealand Institute.

Another conference on the control of wild life in New Zealand was held on the 24th November, and the New Zealand Institute was represented by Dr Cockayne and Professor Kirk.

Australian and New Zealand Association for the Advancement of Science: On the 25th February, 1930, it was resolved that Dr H. H. Allan, Dr P. Marshall, and Professor W. N. Benson should represent the New Zealand Institute at the Brisbane meeting of the Association in May. Professor Benson and Dr Allan found it impossible to attend. Dr Marshall's report will be presented to the Annual Meeting.

Standards Laboratory: At a meeting of the Standing Committee on the 20th February, 1930, Dr Farr was appointed to represent the Institute on the Technical Advisory Committee to be set up in connection with the establishment of a Standards Laboratory.

Fifth International Botanical Congress: As Dr Cockayne was unable to attend this congress, held in Cambridge in August, 1930, Dr H. H. Allan was appointed to represent the New Zealand Institute.

Bequest of Slides: The solicitors of the late Mr J. Crosby-Smith wrote on 9th May, 1930, that his coloured lantern slides of the New Zealand flora had been bequeathed to the New Zealand Institute on condition that they were housed in a fireproof building and from time to time lent out for lecture purposes at the discretion of the Institute. The Otago Institute requested that it might have the custody of these slides and it was decided to comply with the request.

Tongariro National Park: At a meeting of the Standing Committee held on the 25th February, 1931, Mr Aston reported on the action taken by the Board in connection with the hostel and the liquidation of the company which had control of it. His report and that of the Tongariro National Park Board will be presented at the Annual Meeting.

Lord Rutherford of Nelson: General satisfaction was expressed when it was known that Sir Ernest Rutherford's name was included in the New Year Honours, and on the 20th January, 1931, the following resolution was unanimously carried:—"That the hearty congratulations of the New Zealand Institute be sent to Lord Rutherford on his eminent position in the scientific world. The Institute realises with great pleasure that Lord Rutherford has progressed from a primary school of the Dominion to be one of the leading scientific men in the world, and considers that the present peerage conferred upon him is not only a compliment to his unique services to science, but also a great honour to the Dominion. The Institute also recalls that Lord Rutherford's first scientific paper was published in its own *Transactions.*"

Nature Study in Schools: A resolution passed at last Annual Meeting in regard to the possibility of modifying the syllabus of the Entrance Scholarship examination so as to encourage the study of natural history in its original sense was forwarded to the Registrar of the University of New Zealand, and by him referred to the Professors of Biology in the University Colleges. On the 28th August, the Registrar replied as follows:—

> " . . . The Entrance Board resolved that in view of the report obtained from the Professor in Natural History, the request of the New Zealand Institute be declined."

Science Courses in Schools: As a result of a resolution of last Annual Meeting suggesting to the Minister of Education that the New Zealand Institute should be officially consulted in connection with any proposed changes in the science teaching in primary and post-primary schools, the New Zealand Institute was invited to appear before the Select Committee on Education, and subsequently Professor Kirk, Dr Marsden, Dr Cockayne, and Mr Hudson were appointed a committee to appear before the Select Committee. Professor Kirk found it impossible to act on this committee.

National Parks: A resolution of last Annual Meeting that the Department of Lands and Survey be requested to allow the New Zealand Institute to elect a representative on the Arthur's Pass and Egmont Park Boards was referred to the Minister of Lands. He replied that on the Arthur's Pass Board the Philosophical Institute of Canterbury was represented by Professor Speight, and an additional appointment could not be made without special legislation; and that the Egmont Park Board is comprised of the Commissioner of Crown Lands for the Taranaki Land District, two persons appointed by the North Egmont, and two by the South Egmont Local Committees. On the 10th April the Minister was thanked for his reply and was asked that in the event of special legislation being enacted, the Institute's request should be considered. He consented to do this.

The report was then taken clause by clause, slightly amended, and adopted.

Arising out of the report:

Scenery Preservation: The Hon. G. M. Thomson stated that several interested societies in Dunedin were making a determined effort to have the tops of Mount Cargill, Flagstaff Hill, and Signal Hill classed as scenic reserves, under the control of the City Council of Dunedin, and so prevent any further planting of these areas in pinus insignis, etc.

Change of Names of Incorporated Societies: Mr Oliver stated that the reason for the suggested change of titles of incorporated societies was that it would bring the New Zealand Institute into greater prominence, and that uniformity of title would give a truer conception of what the New Zealand Institute is and of the local societies' connection with it. The suggestion was that the societies should be known as local branches of the New Zealand Institute; for instance, the Wellington Philosophical Society should be known as "New Zealand Institute: Wellington Branch."

The opinions of the various societies on the matter were read, and after a good deal of discussion it was moved by Dr Marsden, seconded by Mr Eliott, and carried:—"That the Board of Governors agrees to any steps necessary in connection with the change of designation of any of the incorporated societies to that of local branches of the New Zealand Institute."

Fellowship New Zealand Institute and National Research Council.

A committee consisting of the President (Dr Farr), Hon. G. M. Thomson, Mr Oliver (convener), and Dr Marsden, was set up to report on the proposed National Research Council and on the Fellowship of the New Zealand Institute.

A meeting of the committee was held in the Dominion Museum on 31st March, 1931, when there were present Dr Marsden, Hon. G. M. Thomson, and Mr Oliver (convener).

The following resolutions were adopted:—

1. That the Fellows of the New Zealand Institute constitute the National Research Council.
2. That the election to Fellowship be in two groups:
   (a) Physics, Chemistry, Geology, Mathematics.
   (b) Biology, Medicine, and all other sciences.
3. That two Fellows from each group be elected each year until the total number of Fellows is 50.
4. That the Committee recommends that the New Zealand Institute impress upon the Government the necessity for obtaining the best scientific advice on all questions of policy.

The above resolutions have been submitted to Dr Farr, who is in agreement with them.

The adoption of the report of the committee on these subjects was moved by Mr Oliver and seconded by the Hon. G. M. Thomson. It was, however, resolved that the report be considered clause by clause. A good deal of discussion took place on the various clauses, and finally it was decided that:—

Clause 1 be: "That the Fellows of the New Zealand Institute with power to co-opt constitute the National Research Council."

Clause 2 be: "That the election to Fellowship be in two groups:
(a) Physics, chemistry, mathematics, geo-physics, meteorology, and astronomy.
(b) Biology, geology, medicine, and all other sciences."

Clause 3 be: "That at least one Fellow from each group be elected each year until the total number of Fellows is 50."

On the motion of Mr Aston, seconded by Professor Easterfield, it was resolved that the report of the Fellowship and National Research Council as amended be referred to the incorporated societies and to the next Annual Meeting.

Summer Time Award Regulation: The recommendation of the convener of the Summer Time Award Committee was that Clause 6 of the Regulations be as follows:—

> "Applications for the award shall be called by public advertisement, and applicants shall be invited to submit a thesis specially prepared on the subject of the award, or the applicants may submit papers already published. The Board shall elect a committee of not less than three experts to make recommendations regarding the award, and where the subject has a medical bearing, expert medical opinion on the value of the theses or publications shall be obtained. In making the award, however, the Board shall not be limited to persons who have made applications."

(Signed) E. MARSDEN,
Convener Sidey Medal Committee.

After much discussion of the foregoing recommendation, it was finally resolved on the motion of Professor Easterfield, seconded by Dr Marsden: "That the fact that an award of the prize and medal is to be made shall be announced in the principal papers of the Dominion not less than six months before the making of the award. Theses and copies of published work may be forwarded to the secretary, and will be considered together with any other evidence which is in possession of the Board. Expert opinion shall be obtained on the matter of any piece of work before it is finally accepted for the reception of the prize."

On the motion of Dr Marsden, seconded by Professor Worley, it was resolved that an announcement be made of notice of intention to award the Sidey Medal on 1st January, 1932, should a candidate of sufficient merit be available.

HONORARY TREASURER'S REPORT.

The Balance Sheet for the 15 months ended 31st March, 1931, shows a debit balance of £38 6s 2d, as compared with a debit balance of £287 19s 8d on the 31st December, 1929.

The old amount due to the Government Printer has been reduced from £521 9s 7d to £147 13s 3d. This balance still owing is all made up by interest, and it could therefore well be written off by the Government, particularly in view of our lessened grant.

Since the close of our financial year, advice has been received that our Statutory Grant has been reduced from £1500 to £750. This drastic cut will necessitate a very material reduction in our printing estimates for the coming year. The utmost that appears available for printing the *Transactions* will be £500. It will be necessary, therefore, to reduce the number of papers and size of the next Volume considerably.

The Trust Accounts maintain their customary satisfactory condition. The Carter Bequest capital now totals £8,256.

The books and accounts have as usual been kept in an excellent manner by the Assistant Secretary.

(Signed) M. A. ELIOTT,
Honorary Treasurer.

NEW ZEALAND INSTITUTE.

STATEMENT OF RECEIPTS AND EXPENDITURE FOR THE FIFTEEN MONTHS ENDED 31ST MARCH, 1931.

Receipts.

	£	s.	d.
Balance as at 31st December, 1929	1,635	15	7
Statutory Grant	1,500	0	0
Levy, Trans. N.Z. Inst., Volume 59	13	1	0
" " " " " 60	231	6	4
" " " " " 61	53	10	0
Publications Sales	87	15	4
Research Grants from Treasury	492	10	0
" " Refunded by Grantees	43	4	2
Contributions Presentation Mr J. C. Andersen	17	17	6
Donation from Sir Thomas Sidey (Medal)	120	0	0
Interest Post Office Savings Bank	39	16	1
Carter Bequest Interest	668	10	7
Hector Memorial Fund Interest	105	11	0
Hutton Memorial Fund Interest	114	8	6
Carter Library Legacy Interest	14	12	4
Summer Time Fund Interest	28	0	6
Endowment Fund Interest	47	11	11
Hamilton Memorial Fund Interest	2	7	2
Trust Funds transferred Bank New Zealand	1,335	17	6
Transfers from P.O. Savings Bank to Bank N.Z.	800	0	0
	£7,351	15	6

Expenditure.

	£	s.	d.
Ferguson & Osborn, Ltd.	1,065	6	11
Government Printer (on Account)	400	0	0
Stationery	9	16	2
Transactions Purchased	10	0	0
Travelling Expenses	51	11	5
Salary	375	0	0
Charges (Insurance, Bank Charges, etc.)	16	0	1
Petty Cash	16	16	0
Research Grants Instalments	377	17	0
Hector Award	60	0	0
Trust Funds Interest Invested	1,450	12	6
Presentation Mr J. C. Andersen	21	0	0
Office Furniture	11	8	0
Transfer to Hector Fund, P.O.S.B. Account	33	0	0
Transfer between Bank N.Z. and P.O.S.B.	1,450	0	0
Interest Credited direct to Trust Accounts	845	17	7
Balance, as under	1,157	9	10
	£7,351	15	6

	£	s.	d.	£	s.	d.
Balance in Bank of New Zealand	208	8	1			
Short Deposit Treasury	0	0	2			
				208	8	3
Balance in Post Office Savings Bank				943	11	0
Petty Cash in Hand				5	10	7
				£1,157	9	10

M. A. ELIOTT, Hon. Treasurer.

The Audit Office having examined the Balance Sheet and accompanying Accounts required by law to be audited, hereby certifies them to be correct

G. F. C. CAMPBELL,
Controller and Auditor-General.

NEW ZEALAND INSTITUTE.

Statement of Liabilities and Assets as at 31st March, 1931.

Liabilities.

	£	s.	d.
Carter Bequest Capital Account	8,256	16	2
Hector Memorial Fund Capital Account	1,184	18	1
Hutton Memorial Fund Capital Account	1,314	8	6
Hamilton Memorial Fund Capital Account	57	15	1
Carter Library Legacy Capital Account	100	0	0
Summer Time Fund Capital Account	500	2	6
Endowment Fund Capital Account	647	19	6
Carter Bequest Revenue Account	33	9	1
Hector Memorial Fund Revenue Account	109	12	9
Hutton Memorial Fund Revenue Account	171	8	6
Hamilton Memorial Fund Revenue Account	4	3	4
Carter Library Legacy Revenue Account	49	5	6
Summer Time Fund Revenue Account	147	18	0
Endowment Fund Revenue Account	103	0	0
Library Fund	176	19	4
Government Printer	147	13	3
Ferguson & Osborn, Ltd.	220	4	3
Research Grants Fund	807	1	11
	£14,032	15	9

Assets.

	£	s.	d.
Inscribed Stock	9,868	17	11
P.O. Inscribed Stock	2,135	6	10
Bank of New Zealand	208	8	3
Post Office Savings Bank	943	11	0
Petty Cash in Hand	5	10	7
Outstanding Accounts	259	2	9
Carter Bequest P.O.S.B. Account	33	9	1
Hector Memorial Fund P.O.S.B. Account	109	12	9
Hutton Memorial Fund P.O.S.B. Account	171	8	6
Hamilton Memorial Fund P.O.S.B. Account	61	18	5
Carter Library Legacy P.O.S.B. Account	49	5	6
Summer Time Fund P.O.S.B. Account	147	18	0
Balance of Liabilities over Assets	38	6	2
	£14,032	15	9
To Balance	£38	6	2

NEW ZEALAND INSTITUTE.

Revenue Account for the Fifteen Months Ended 31st March, 1931.

Expenditure.

	£	s.	d.
Balance at 31st December, 1929	287	19	8
Printing, Stationery, etc.	1,342	19	0
Salary	375	0	0
Travelling Expenses	51	11	5
Charges (Insurance, Bank Commission, Audit, etc.)	19	5	4
Petty Cash	16	16	0
	£2,093	11	5

Income.

	£	s.	d.
Statutory Grant	1,500	0	0
Levy and Publications Sold	555	5	3
Balance	38	6	2
	£2,093	11	5
To Balance	£38	6	2

NEW ZEALAND INSTITUTE TRUST ACCOUNTS.

Revenue Accounts.

Carter Bequest for the Period Ended 31st March, 1931.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Interest Invested	700	7	6	By Balance at 31/12/29 ..	65	6	0
„ Balance	33	9	1	„ Interest	668	10	7
	£733	16	7		£733	16	7
				By Balance	£33	9	1

Hector Memorial Fund for the Period Ended 31st March, 1931.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Cheque (Dr Holloway)	60	0	0	By Balance at 31/12/29 ..	64	1	9
„ Balance	109	12	9	„ Interest	105	11	0
	£169	12	9		£169	12	9
				By Balance	£109	12	9

Hutton Memorial Fund for the Period Ended 31st March, 1931.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Interest Invested	100	2	6	By Balance at 31/12/29 ..	157	2	6
„ Balance	171	8	6	„ Interest	114	8	6
	£271	11	0		£271	11	0
				By Balance	£171	8	6

Hamilton Memorial Fund for the Period Ended 31st March, 1931.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Half Interest to Capital Account	1	3	7	By Balance at 31/12/29 ..	2	19	9
„ Balance	4	3	4	„ Interest	2	7	2
	£5	6	11		£5	6	11
				By Balance	£4	3	4

Carter Library Legacy for the Period Ended 31st March, 1931.

Cr.	£	s.	d.
By Balance at 31/12/29 ..	34	13	2
„ Interest	14	12	4
	£49	5	6
By Balance	£49	5	6

Summer Time Fund for the Period Ended 31st March, 1931.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Certificate of Title ..	0	2	6	By Cheque Sir Thos. Sidey	120	0	0
„ Balance	147	18	0	„ Interest	28	0	6
	£148	0	6		£148	0	6
				By Balance	£147	18	0

Endowment Fund for the Period Ended 31st March, 1931.

Dr.	£	s.	d.	*Cr.*	£	s.	d.
To Interest Invested	150	2	6	By Balance at 31/12/29 ..	165	14	6
, Balance	103	0	0	„ Interest at P.O.S.B. ..	39	16	1
				„ Interest on Investments	47	11	11
	£253	2	6		£253	2	6
				By Balance	£103	0	0

The Honorary Treasurer moved the adoption of the various financial statements, seconded by Professor Park, and carried.

It was resolved that in view of the reduction in the Institute's grant, the Prime Minister be approached regarding the wiping out of the debt to the Government Printer.

5. REPORT OF THE PUBLICATION COMMITTEE.

The general conditions of financial stringency have much hindered the publication of the *Transactions* during the past year.

The last part of Volume 60 was issued in March, 1930, completing a volume of 665 pages with 63 plates. Part 4 contained 145 pages and 4 plates.

Of Volume 61, Parts 1 and 2 were each of normal size; Part 1 contained 215 pages and 38 plates, Part 2 contained 224 pages and 39 plates. The remainder of the volume had to be compressed into one small double-part of 126 pages with 24 plates, making a total for the volume of 566 pages and 91 plates. This was issued in November, 1930.

Since then, publication of the *Transactions* has been unfortunately suspended, pending the decision of the Government with regard to the Annual Grant. The reduction from £1500 to £750, which has now come into effect, will severely cripple the activities of the Institute, and a much reduced volume will result.

Part 1 of Volume 62, which is now being printed by Messrs Ferguson & Osborn, Ltd., will be a small part of 77 pages. A new tender from the Otago Daily Times has been accepted to publish the remainder of this volume.

It will be necessary for authors to give the most careful consideration to the condensation of their papers and reduce the number of illustrations to a minimum.

For the Publication Committee,

D. M. Y. SOMMERVILLE,
Hon. Editor.

In presenting the report of the Publications Committee, the Hon. Editor stressed the necessity of authors curtailing the length of their papers, and suggested that in papers where there are many illustrations, authors should be asked to contribute towards the cost of the illustrations. The report was adopted. On the motion of Dr Marsden, seconded by the Hon. G. M. Thomson, it was resolved to circulate the report to the incorporated societies.

Transfer of Printing to Dunedin: It was reported that tenders had been called from all the large printing firms in New Zealand, and the lowest tender was that of the Otago Daily Times, of Dunedin. It was therefore decided that in view of the very limited amount of money available, the printing of the *Transactions* should be transferred to the Otago Daily Times Company. On the motion of Mr Aston, seconded by Professor Park, it was resolved that the Hon. G. M. Thomson be appointed to act for the Hon. Editor in Dunedin, and see the *Transactions* through the press.

REPORT OF HONORARY LIBRARIAN.

It is satisfactory to report that the Library continues to grow rapidly by accessions through exchanges with other learned societies, and is being used to an increasing extent by research workers.

Owing to the increasing congestion it will be necessary to store certain serials temporarily in a less accessible place, there being no further room for expansion in the present premises at Victoria University College.

Two new exchanges have been entered into during the year.

When better conditions arise there should be put in hand the matter of preparing a complete catalogue, which would be available for the use of readers. A cognate matter which will require attention is the revision of Mr Archey's Index of Scientific Periodicals in New Zealand Libraries. These two matters are of the greatest importance in order that the fullest use may be made of the resources of the Institute's Library.

D. M. Y. SOMMERVILLE,
Honorary Librarian.

The report of the Honorary Librarian, Professor M. Y. Sommerville, was adopted.

Report of Research Grant Committee.

The Research Grants Committee had three meetings during the year. An effort was made to find from each grantee how long he expected his research to continue and how much he now expected it to cost. Replies were received from all but three grantees, and the information supplied was of great assistance in allocating new grants.

The cessation of the supply of funds from the Government will leave the Committee little to do during the coming year.

In response to an inquiry from the Standing Committee a statement was prepared embodying the principles which the Committee thinks should guide it in allocating grants.

F. W. Hilgendorf,
Chairman Research Grants Committee.

Reports of Research Grantees for Period Ended 31st March, 1931.

Dr C. E. Adams, in 1925, was granted £200 for a research on southern stars. It was proposed to purchase an interferometer, but it was found that the amount was quite inadequate. Mr Hargreaves, in consultation with Dr Comrie, of London, spent a great deal of time on the consideration of a design that could be worked up, and it was decided that he be given £10 out of the grant, and that he be asked to submit a report on his work for the future information of the Institute. This has been the only expenditure from the grant.

Dr H. H. Allan, in 1923, was granted £30 for a research on cocksfoot. He reported on the 8th April, 1931, that during his absence from New Zealand the work had been carried out by Mr Malcolm, of the Feilding Agricultural High School. The three selected plants were increased vegetatively and seed secured from each; one set has been abandoned owing to high susceptibility to rust. General observations confirm the opinion that extra-New Zealand cocksfoots do not provide material at all approaching those long-grown in New Zealand. The selected cocksfoot is fine-leafed, succulent, and much less fibrous in leaf tissues than the common commercial forms. No further expenditure from the grant will be necessary, and Dr Allan refunded an unexpended balance of £10 16s 6d.

Dr H. H. Allan, in 1924, was granted £50 for a research on Mount Egmont forest. He reported on the 8th April that owing to his absence in England, no further field work had been accomplished. He hopes to carry the investigation to a conclusion during the next season, and as the remaining work will not require financial assistance, he refunded the balance, namely £23 0s 10d.

Mr G. Archey, in 1926, was granted £40 for a research on New Zealand Chilopoda. He reported on the 9th April that collecting had been conducted in the Auckland District, at Taupiri, Mamaku, Rotorua, Urewera, and Waikaremoana. A report on the order Geophilomorpha had been prepared, and will be presented for publication after the incorporation of this season's results and the results of a comparison made with type material in England. A further season's collecting should provide material for a final paper revising the whole of the New Zealand Chilopoda. Collecting expenses for the period amounted to £2 15s 6d, leaving a balance in hand of £5 6s 4d.

Mr B. C. Aston, in 1928, took over from Dr J. Malcolm £9 16s 7d, balance of a grant for research on Pukateine. On the 12th March, Mr Aston reported that Professor Barger, F.R.S., of Edinburgh University, to whom quantities of the bark of Pukateine had been sent, reported that the bark had been extracted and the alkaloids separated and examined. He had been able to complete the determining of the constitution of one of the alkaloid pukateine. Dr Fogg, of the Otago Medical School, is also working on the alkaloid which has been prepared by Mr Aston. There is now a quantity of the pure alkaloid pukateine in hand available for further physiological investigation in New Zealand. An expenditure of £1 was incurred, leaving a balance of £7 6s 7d.

Professor W. N. Benson, in 1925, was granted £50 for preparing rock sections of Dunedin region. The whole of the grant has now been expended. Fossils discovered at Boulder Hill have been described by Drs Finlay and Marwick, and are an almost unique fauna. Their features determine the age of the coal in this neighbourhood and that of the oldest fossiliferous beds. The description of the fauna was therefore essential to the understanding of the district. The expenditure for the period amounted to £19 17s 9d.

Professor W. N. Benson was, in 1929, granted £150 for a geological expedition to Preservation Inlet. The expedition took place in January-February. 1931, and on the 24th February, Professor Benson wrote summarising the results achieved. He stated that it had been proved that Preservation Inlet region was the correct place to make a first attack on the detailed investigation of the south-western portion of the Dominion. The laboratory examination of the specimens and the preparation of the final account of the expedition's work may take more than a year to complete. The whole grant was fully expended.

Mr A. E. Brookes, in 1927, was granted £40 for a study of the Coleoptera of the islands off the Auckland coast. He reported in November that last summer a visit was made to Great Barrier Island. The season proved a very dry one, and beetles were not at all plentiful, but interesting material was found in leaf mould. The result of the trip was that 690 specimens were collected, covering 157 species and 122 genera; 34 doubtful species will have to be compared with types in the British Museum before they can be satisfactorily determined. Expenditure amounts to £23 16s 2d.

Dr G. H. Cunningham, in 1928, was granted £25 for a Mycological Survey of the Tongariro National Park. He reported on the 27th March, 1931, that during the past season he had had little opportunity for extending the survey. However, fourteen days were spent in the Park during the Christmas-New Year holiday season, and nine of these were spent in collecting extensively on the northern slopes of Mount Tongariro, special attention being paid to the fungi of the Ketetahi Blowhole. Collecting was also done in other parts of the Park, and in all some 47 species have been collected, and as time permits these will be named. No expenditure from the grant was incurred during these visits.

Dr K. M. Curtis, in 1928, was granted £50 for research on the control of black rot in hops. On the 31st March, she reported that the tests comprised treatment to diseased soil before planting new sets; treatment to new sets before planting them in diseased soil; treatment to soil adjoining infected soil, when the plants were already planted. The last method has been found to be most effective. Generally speaking, sulphate of iron gave the best results of the annual treatments. It was applied at the rate of 1lb per hill over as wide an area as possible round the hills. The whole of the grant was expended and the experiments are being continued.

Dr H. G. Denham, in 1928, was granted £75 for research on the essential oils of *Pinus Insignis*. On the 4th April he reported that the work was complete, and a paper covering the results obtained has been written by Mr T. H. McCombs and published in the last number of the Journal of Science and Technology. The expenditure during the year amounted to £23 12s 6d, leaving a balance in grantee's hands of £9 9s 4d.

Dr C. Coleridge Farr, during 1924-1927, was granted £400 for a research on helium in New Zealand. He reported that the examination of the possible sources of helium had been carried as far as desirable, and a paper showing the results was published some two years ago. Expenditure amounted to £254 15s 11d; a balance of £45 4s 1d is in the Institute's Research Fund Account, and the remaining £100 has never been paid over by Treasury.

Dr C. Coleridge Farr, in 1922, was granted £15 for research on the physical properties of gas-free sulphur. He reported that although it has not been possible to proceed with the research during the last year, more work is contemplated. There is an unexpended balance of £4 18s 1d.

Professor D. C. H. Florance, in 1928-29, was granted £58 for research on oscillation crystals and supersonic waves. He reported on the 14th April that a preliminary account of the work on quartz crystals was published in the Philosophical Magazine, vol. 8, 1929. The work had been continued by Mr Harding, M.Sc., and a thesis on the subject had been submitted to the University

of New Zealand. Since Mr Harding's departure to England, Mr Peddie has continued the work, and the problems under investigation are comparison of the modes of vibration of different crystals with a view to determining which modes are purest; investigation of the sound field produced by thin vibrating crystals—this has been explored by powder methods and is also being investigated by light methods; and investigations of the effect of amplitude of vibration, and of frequency on the velocity of sound waves produced by piezo-electric crystals. The whole of the grant has been expended.

Dr O. H. Frankel, in 1929-30, was granted £42 12s for research on the cytology of New Zealand plants. He reported on the 4th April that during the past season a large number of fixations were made from various species of the genus Hebe, altogether over 30 species. Some chromosome counts on temporary stains helped to establish definitely that Hebe is a polyploid genus, comprising species with 20 and 40 chromosomes, and probably further related numbers. Fixation in the genus Coprosma proved more difficult, but some definite counts were obtained. Expenditure amounted to £17 10s 11d.

Dr J. K. H. Inglis, who, from 1923-1930, has been granted £125 for research on the essential oils of native plants, reported that work during 1930 was done on the essential oils in the New Zealand Pepper Plant and in Black Pine. Considerable progress was made with both materials, and papers will be ready shortly for publication. Quantities of oil have been extracted from White Pine and Totara, and these, together with oil from Red Pine, are being worked on now. Signs of very decided seasonal variation in the oil constitution have been found, and further work is planned to investigate these changes. Repairs have been carried out on the large still. The whole of the grant has been expended.

Mr G. Jobberns, in 1926, was granted £75 for correlation of shore platforms of the N.E. coast of the South Island. He reported that he has two short papers published in Volume 59, *Trans. N.Z. Inst.* The whole of the grant has been expended.

Mr F. V. Knapp, in 1925, was granted £25 for investigation of Maori Artifacts. He reported that owing to his absence in England, he has not completed this research. He had hoped to explore camping sites at Golden Bay and Pakawai in 1931, but finds the curtailment of his grant will not allow of this, as the small balance of £3 8s 6d available would not be sufficient, and he has therefore decided that it will be best to relinquish the amount. The total expenditure has been £9 14s.

Mr A. W. B. Powell, in 1925, was granted £50 for a survey of the Molluscan Fauna of the Manukau Harbour. He reports that several papers have already been published, and considerable progress with the Manukau Harbour survey has been made during the year. This survey requires at least another year's collecting and seasonal observations before it will be possible to finalise the paper. The whole of the grant has been expended.

Research Committee, Auckland Institute, in 1925, was granted £65 for an ecological survey of the Inner Waitemata Harbour. Through Mr Powell, it reported on the 8th April that during the year three whole days had been devoted to dredging operations, and a good series of samples and specimens had been taken. Work on the special reports and general ecological work is proceeding. There is an unexpended balance of £3 6s 11d.

Mr F. W. Short, from 1925-29, was granted £189 for investigations upon the constitutions of several constituents of New Zealand essential oils. He reported on the 4th April that a paper describing the isolation of aromadendrene from the oil of eucalyptus variflora had been published in the Journal of the Royal Society of N.S.W., 1930, and he enclosed a reprint of the paper. Work is now being done on the chemistry of totarol from *Podocarpus totara*, and of podocarpic acid from *Dacrydium cupressinum* and *Podocarpus dacrydiodes*. The whole of the grant is spent.

Mr H. F. Skey took over in 1927 from Captain Isitt a grant of £36 10s 9d, and later was granted an additional £175. He reported that the research is still in progress, but the results of flights are now regularly forwarded to the

Director of Meteorological Services, whose department bears the expense. Similar pilot balloon observation has been initiated lately in Wellington and Auckland, and it is desirable that the Christchurch flights should be continued for some years at least, so as to enable adequate correlation of results with synoptic charts. Expenditure amounts to £173 3s 7d.

Mr H. D. Skinner, in 1929, was granted £20 for a research on line fishing among Maoris. He reported on the 1st April that Mr Teviotdale visited sites along the north shore of Foveaux Strait. The expenditure amounted to £8 16s 7d, and £5 was refunded by grantee.

Professor R. Speight, in 1928, was granted £150 for geological work in Mount Somers district. He reported that the area has been almost completely surveyed. Portions have been mapped by compass and chain survey, but owing to the departure of Mr Sylvester from Christchurch, mapping on the original plan has been discontinued, and reliance placed on Lands and Survey maps for the fixing of boundaries. A fossil collection has been made and will be dealt with by Dr Marwick, who has kindly consented to do so. A series of analyses of igneous rocks has been made by the Dominion Laboratory, and further analyses of limestone, coals, and fireclays promised. The economic possibilities of the district are being considered. Only £100 of the grant has been paid over by Treasury, and the expenditure has amounted to £32 12s 1d.

Dr G. H. Uttley, in 1928, was granted £35 for research on Bryozoa. He reported that owing to his removal to Invercargill he had temporarily to discontinue the work, but it has now been resumed. There is an unexpended balance of £6 11s 2d.

Messrs Wild and Zotov, who, in 1928, were granted £10 for research on the sexuality of New Zealand Coprosma, reported that a paper on the preliminary studies has been published in the *Transactions*. The extent of the parthenogenetic reproduction is being studied in the species *C. grandifolia*, *C. lucida*, and *C. robusta*. No definite results are yet confirmed. Hybridism is also being investigated. An account of these studies is in an advanced stage of preparation. During the year expenditure amounting to £2 6s 8d was incurred.

Professor F. P. Worley, in 1923, was granted £25 for research on the chemistry of essential oils of New Zealand Flora. He reported that no expenditure was incurred during 1930-31.

Mr R. M. Laing, in 1924, was granted £100, and in 1929, an additional £25 for research on Marine Algae. He reports that the work is still in progress, and several collecting trips have been made during the last fifteen months. The second part of an investigation of the New Zealand Gigartinas has been sent to the editor of the *Transactions* for publication, and the third part is in active preparation, the work being done with Mr H. W. Gourlay. There remains an unexpended balance of only £1 3s.

On the motion of Professor Speight, seconded by Professor Park, the report was adopted.

Proposed Research Grant Policy.

1. In making a grant, consideration should be given to the importance of the research, the training and capacity of the grantee, and the opportunities he has of prosecuting the research.

2. Preference should be given in the first instance to investigations which appear to have an economic bearing, but purely scientific investigations should be by no means excluded. (See Committee Report—Trans. Vol. 49, p. 536, 1917).

3. There is no difference in eligibility for grants between Government officials, employees of institutions such as universities, and individuals not in paid employment.

4. The fact that an applicant has access to the laboratory or field and apparatus supplied by the institution to which he belongs, may be a recommendation for a grant, as this access must facilitate his research.

5. At the same time, care should be taken that grants are not used for the purchase of books or equipment that the institution to which the grantee belongs might reasonably be expected to have purchased for its own work, but only for equipment beyond the scope of the institution's work.

6. Reasonable travelling expenses on a research are regarded as a suitable object for a grant, but applications for living expenses while travelling will not in general be looked upon with favour.

7. The financial position of the applicant in respect of his ability to undertake the research without monetary assistance may be taken into account when an application is being considered.

F. W. HILGENDORF,
Chairman Research Grants Committee.

It was resolved that the policy as set out by the Research Grants Committee, with the deletion of paragraph 2, be adopted.

TONGARIRO NATIONAL PARK.

REPORT OF NEW ZEALAND INSTITUTE'S REPRESENTATIVE ON PARK BOARD.

As representative of this Institute on the Board of the Tongariro National Park, I have to report a very great increase in the responsibilities of the Park Board during the past year.

Two full meetings of the Board, held at the Chateau, and four meetings of the Executive, held at Wellington, were attended by your representative.

At the time of writing the last report, the writer had not visited the new building designated as "hostel," a term quite inadequate to convey an idea of the palatial nature of the building erected as a private venture to attract and accommodate visitors to the Park. The steps leading up to this development are given in my report for 1929. (See Tongariro National Park Act, 1922, and Section 36 Finance Act, 1928). The Tongariro National Park Tourist Co., Ltd., sought and obtained power from Parliament to borrow another £20,000 for the purpose of erecting and equipping a hostel and laying-out of grounds (see Section 45 Finance Act, 1929). The Public Trustee, who was secured in repayment of principal and interest by debentures issued by the Board with Government guarantee, had therefore lent to the Park Board £60,000 for the purpose of lending to the company for construction and furnishing the hostel, the Board being secured by mortgage and chattel security lease on the furniture, etc. The Board also lent an additional sum at its disposal, making altogether £63,750 secured. The Company defaulted in the payment of the December, 1930, instalment of interest, a little over one year after the opening of the Chateau Tongariro, as it is now called. Matters received the earnest consideration of the Board, and after several meetings it was decided at a full meeting of the Board, held at the Chateau, to take over the management and apply to the Supreme Court, Wanganui, to sell the lease, including the chattels, by auction. This was effected at Wanganui on 30th March, 1931, the Park Board purchasing the property for £61,000 (£46,000 lease, £15,000 chattels). Throughout the changes in the management from the Company to the debenture holders, and from these to the Board, the Chateau did not close its doors, but continued to run as a going concern. On February 3, 1931, the disastrous Hawke's Bay earthquake was severely felt at the Chateau, but it had no injurious effect on the building. The financial statements furnished to the Board by the Company were submitted to this Institute's honorary treasurer, Mr M. A. Eliott, who, inter alia, reported as follows:—

> "It is interesting to note that the actual receipts total very closely the estimated receipts when the Company was formed, when it was originally estimated that the total receipts would be £29,500, of which £24,650 would represent payments for board. . . . With careful and economic management it should be possible to pay interest on the £63,000 owing to the Park Board."

It will therefore be seen that the default of the Company was not due to want of patronage on the part of the public, seeing that the original estimates of attendance were fully realised.

While every sympathy must be felt for those shareholders and debenture holders who have lost heavily in their venture, they have the consolation of knowing that their lost capital has not only been the means of erecting a permanent memorial to their enterprise, but has enabled the Board to exhibit to

all classes of visitors requiring every grade of accommodation a National Park which is destined to become famous throughout the world.

The Chateau, said to be the best hotel in New Zealand, together with the lodges and outside cubicles situated at 3800 feet above the sea, is capable of housing over 300 guests. There is an eighteen-hole golf course being laid out in front of the entrance, while tennis and other games can be played at the Chateau. Winter sports are a special attraction, and a motor road is in course of construction, which will take the enthusiast up 2000 feet higher than the Chateau to the ski grounds. The National Park railway station is some ten miles from the Chateau, and as supplies of food, milk, butter, meat, vegetables, and even cut flowers have to be brought from even a longer distance than from this station, the question of the lease or the establishment of a farm to supply the Chateau must arise. The views of this Board of Governors are sought as to the desirability of allowing further areas of tussock lands in the Park to be broken up and grassed for cow and sheep farming; pigs are already raised and fattened at the Chateau on kitchen refuse, excellent bacon being the only food product at present raised there.

It appears probable that under the management of the Chateau by the Board, it will be far easier to exercise control over the amenities of the Park than if a portion is leased to a money-making company. One has only to look at the care exercised at the Waitomo Hostel in the preservation of the caves and their contents by the Tourist Department officials, who realise that the wonders there are an asset which must not be destroyed, to understand that the best guarantee that the birds, forests, and vegetation generally will be preserved intact at the Tongariro National Park is that everything, including the Chateau, should be under direct control by the Park Board.

(Signed) B. C. Aston,
N.Z. Institute Representative.

Mr Aston moved his report as representative of the Institute on the Park Board, which was adopted. He asked for an expression of opinion as to whether he should advocate the establishment of a farm in the Park to supply the Chateau with produce. It was resolved to leave the matter to Mr Aston's discretion. On the motion of Mr Eliott, seconded by the Hon. G. M. Thomson, it was resolved that the question of holding the next Science Congress at Tongariro National Park be kept in view.

Report of New Zealand Institute's Representative on the New Zealand Institute of Horticulture.

As recorded in my 1929 report (see Vol. 60. p. 15, May, 1929), the New Zealand Institute of Horticulture continues to do good work. At the Eighth Annual Meeting and Conference a variety of subjects was dealt with, and the Banks Annual Lecture, inaugurated in 1926, was delivered by Mr W. R. B. Oliver, a member of the Board, who took as his subject, "National Botanical Gardens." Monthly meetings of the Executive Committee are held in Wellington, all of which during the present year have been attended by your representative.

The first National Flower Show, under the auspices of the above Conference, representing the New Zealand Horticultural Trades Association, the Association of Directors of Parks and Reserves, and the New Zealand Institute of Horticulture, was highly successful, and an official dinner was a further attraction of what will in future be known as "Horticultural Week."

The most outstanding of the Institute's activities are the granting of the Diploma of the Institute by examination or otherwise, and the issue of a very promising Journal of Horticulture. The shrinkage of funds, due to the depression, has somewhat curtailed activities in publishing, but an effort is being made to increase the membership, the subscription being only 12s 6d per annum, of which 2s 6d goes to the local branches. It is hoped that a systematic canvass will increase the membership to such an extent that the Institute will be able to maintain its activities with little curtailment, and provision is being made for

this canvass to be carried out. The Institute has in the past received a Government grant of £100 per annum, the income from other sources being about £250, from receipts of fees from examinations and subscriptions from members.

(Signed) B. C. Aston.

Mr Aston presented his report as representative of the New Zealand Institute on the New Zealand Institute of Horticulture. The report was adopted.

Board of Trustees National Art Gallery and Dominion Museum.

As Vice-President, the writer is one of the two representatives of the New Zealand Institute on the Board of Trustees of the National Art Gallery and Dominion Museum, constituted by the National Art Gallery and Dominion Museum Act, 1930.

Since the Act was passed, five meetings of the Board have been held, and attended by your representative.

The new Board had inherited certain arrangements made by their predecessors, including the site chosen for the buildings, the plan for the erection of the new buildings, and the contracts made in connection therewith, and the necessity of the demolition of the great brick structure known as the Mount Cook Barracks or Gaol, which occupied the position chosen as site for the new Art Gallery and Museum. At the first meeting the amount of subscriptions promised, collected, or accrued interest thereon was stated to be £98,128 2s 1d, of which £56,934 14s 7d was in the bank.

The erection of the carillon tower and steps has been authorised, and is being proceeded with, the tender of P. Graham & Co. for £17,110 being accepted. The contract for the demolition of the barracks has been accepted, and this work is now almost completed.

The important question of the building stone to be used was a matter in which the writer took particular interest, seeing that Dr Marshall had expressed very decided views in preference of New Zealand stone instead of Portland stone. In looking into the matter, it appeared to the writer that Dr Marshall's opinion was unassailable, especially as it was supported by very positive opinion from the Chief Engineer of the Public Works Department (Mr Furkert). At the meeting on 3rd February, which the President's deputy (Professor Kirk) was unable to attend, I appointed Dr Marshall to act for the President at the Board, and this gave the opportunity for him to explain his preferences for Putaruru vitric tuff over Portland stone. The Board at this meeting adopted the New Zealand stone.

Errata.—After the word "arrangements" in paragraph 3, insert "validated by Section 11 of the above Act." After the word "predecessors" in paragraph 3, add "the provisional Board of Trustees constituted under Section 64 Finance Act, 1929."

(Signed) B. C. Aston.

Mr Aston, as one of the Institute's representatives on the Board of Trustees, read his report, which was adopted.

Report on Meeting of the Australasian Association for the Advancement of Science.

By Dr P. Marshall.

In accordance with instructions, I duly represented New Zealand at the meeting of the Australasian Association for the Advancement of Science, held in Brisbane, May 28—June 4.

The meeting was attended by a large number of representative scientific men from all States of the Australian Commonwealth. It happened that I was the only New Zealand delegate present, though two other scientific men had accepted nomination as president of two of the sections.

At the first Council meeting on Wednesday, May 28, a letter was read from Otago University, asking that the name of the Association be changed in some way so as to indicate the definite inclusion of New Zealand. This matter had

been brought before the Council on several occasions, but there has always been a decided wish to continue the old title, which has stood for over 30 years. I spoke on this subject at the Council meeting, pointing out the want of precise meaning in the title. A small committee, consisting of the President, General Secretary, and myself, was appointed to consider the question and report later. At the reception by the Lord Mayor of Brisbane in the Town Hall in the afternoon of the same day, I was asked to reply to the speech of welcome on behalf of the visitors. Since several of the earlier speakers had referred to the use of the word "Australasian," with pointed reference to the New Zealand delegate, it seemed advisable to refer to the matter again. I therefore pointed out that the wish for a change in the title in no way implied antagonism to the Continent of Australia, but merely a wish to maintain the individuality of New Zealand.

It seems that a favourable impression was made, for at the final meeting of the Council, the report of the committee was adopted, viz.: "In future the title of the Association be 'The Australian and New Zealand Association for the Advancement of Science.'" Thus the New Zealand objection was fully met. I feel that New Zealand is greatly indebted to the kindly consideration and accommodating feeling of Australian scientific men in thus agreeing to a change of title which has become established by such long usage, and for which many members had developed an affectionate regard.

The working sessions of the Congress began on May 29, and lasted until June 5. My work was mainly in association with the geological section, at which there was a large attendance. Many subjects were presented for discussion, as shown in the programme sent in with this report. Each of the subjects was spoken to by a large number of members, and the exchange of views cannot fail to be profitable to all. It is certainly of great importance to hear at first hand the Australian view in regard to the many geological questions on which the Australian Continent is equally involved with New Zealand. From a commercial standpoint the discussion on geophysical methods for discovering mineral oil was probably the most important. The other discussions were of a more technical nature, though, in general, the subjects were treated in a manner that was more practical than academic.

It will perhaps be remembered that a special invitation had been extended to me to deliver an evening lecture to the whole Association on the subject of the Coral Reefs. This was duly delivered on the evening of May 29, and I enclose a letter kindly sent me by Professor Richards, chairman of the committee of local organisation in regard to it.

I think it is a matter for regret that time and distance, as well as the question of expense, so often prevent New Zealand scientists from attending the meeting of the Association. I feel that they would derive a stimulating encouragement in their work, and would gain great advantage from personal discussion with men who are studying the same subjects as they themselves, often from a slightly different angle.

His Excellency the Governor-General, Sir John Goodwin, was present at several of the public functions and public addresses, and entertained the Association at a garden party at Government House. The Lord Mayor and Corporation of Brisbane gave an official reception at the Town Hall, and afterwards the Government of Queensland entertained members at a river excursion.

On all sides I was treated with the utmost hospitality and cordiality as the representative of the New Zealand Government and of scientific bodies in New Zealand.

(Signed) P. MARSHALL.

The report of Dr Marshall, who represented the New Zealand Institute at the Brisbane meeting of the Association, was adopted.

GREAT BARRIER REEF COMMITTEE.

Five meetings were held during the year 1930.

The British Barrier Reef Expedition having returned to England, the Committee has decided that, apart from expenditure in printing, no large scheme of expenditure should be undertaken at present.

Mr F. W. Moorhouse has been appointed by the Queensland Government to carry on marine biological work on the reef. This is to be mainly of an economic nature, including investigations on turtle, beche-de-mer, sponges, fish, and oysters.

The Trustees of the British Museum have agreed to undertake the full publication of the results of the British Barrier Reef Expedition.

(Signed) W. R. B. OLIVER,
N.Z. Institute Representative
on the Committee.

This report, presented by Mr Oliver, the Institute's representative on the Committee, was adopted.

Hutton Grant Applications: Two applications for grants from the Hutton Fund, one from Mr F. J. Turner and one from Mr C. E. Christensen, were read and referred to the Research Grants Committee for recommendation to the Standing Committee.

British Association for the Advancement of Science: An invitation to attend the Centenary of the British Association for the Advancement of Science, to be held in September, 1931, was received. It was resolved to appoint Professor D. M. Y. Sommerville to represent the Institute at this celebration. It was resolved that the preparation of a scroll containing the congratulations of the New Zealand Institute on the occasion of the British Association's centenary be left in the hands of the President and Vice-President.

International Research Council: It was resolved to ask Sir Richard Glazebrook, F.R.S., to act for the New Zealand Institute at the forthcoming General Assembly of the International Research Council at Brussels in July.

Pacific Science Congress: Invitations from the National Research Council of Canada to send delegates to the Fifth Pacific Science Congress, to be held at Victoria and Vancouver in June, 1932, were received. It was resolved that the matter be left in the hands of the Standing Committee to appoint delegates.

The possibility of an invitation being sent to the Pacific Science Congress to meet in New Zealand in 1935 was discussed, and it was left in the hands of a committee consisting of Mr Aston, Dr Marsden, and Dr Marshall, to report to the Standing Committee on the matter.

Faraday Celebrations: The Institute received an invitation to send a delegate to attend the Faraday Celebrations, which will commence on 21st September, 1931. It was resolved that Professor Sommerville should represent the Institute.

University of Cambridge: The University of Cambridge is commemorating the centenary of James Clerk Maxwell on the 1st and 2nd October, 1931, and the New Zealand Institute has been invited to send a representative. It was decided to ask Professor Sommerville to represent the Institute at this centenary also.

Professor Sommerville thanked the Board for the honour of representing the New Zealand Institute at these various functions.

Notices of Motion were then taken:

(1) *Vice-President:* On the motion of Mr B. C. Aston, seconded by Professor Kirk, it was resolved that a committee consisting of the President-elect, Professor Kirk (convener), and Dr Marsden, be a committee to report and define the duties of the Vice-President, and that the question of an Honorary Secretary be referred to the same committee.

(2) *Hector Observatory:* On the motion of Professor Kirk, seconded by Professor Easterfield, it was resolved that it be a request to the Minister for Scientific and Industrial Research that the name of the Dominion Observatory shall be the Hector Observatory.

(3) *Title of New Zealand Institute:* On the motion of the Hon. G. M. Thomson, seconded by Professor Park, it was resolved that steps be taken to have the word "Royal" incorporated in the title of the New Zealand Institute.

(4) *Secretary:* On the motion of the Hon. G. M. Thomson, seconded by Mr Oliver, it was resolved that Miss Wood's title be altered from "Assistant Secretary" to "Secretary."

(5) *Natural History in Schools:* On the motion of the Hon. G. M. Thomson, seconded by Professor Kirk, it was resolved that this meeting of the Board of Governors draw the attention of the Minister of Education to the action of the Education Department in displacing the teaching of botany in Girls' High Schools, and trusts that Natural History teaching will receive its proper place in the curriculum of all High Schools.

(6) *Dr Cockayne:* On the motion of Professor Kirk, seconded by Professor Easterfield, it was resolved that this meeting express its gratification at the success that is attending the measures taken for Dr Cockayne's restoration to health, and conveys to him its hearty sympathy and good wishes.

(7) *Biology Teaching:* On the motion of Dr Marsden, seconded by the Hon. G. M. Thomson, it was resolved that on account of the national importance of agriculture and industries derived therefrom, and also from the point of view of a balanced education for life, it is the considered opinion of the Board of Governors of the New Zealand Institute that an increased and better teaching of biology should be developed in New Zealand schools, and that this resolution be forwarded to the Prime Minister, to the Minister of Education, and to the Director of Education.

(8) *New Zealand Institute Act:* On the motion of Mr Oliver, seconded by Mr Hudson, it was resolved that a committee be appointed to report to the Standing Committee, alterations required in the New Zealand Institute Act and Regulations. The committee to be Dr Marsden, Mr Aston, and Mr Oliver (convener).

(9) *Natural Science in Schools:* On the motion of Professor Worley, it was resolved that a committee, consisting of Professor Kirk (convener), Hon. G. M. Thomson, Mr Oliver, and Mr Hudson, be set up to go into the teaching of natural science in all schools of the Dominion.

Carter Bequest: Professor Kirk, as convener of the Carter Bequest Committee, read the report the committee had drawn up in connection with the negotiations with the Wellington City Council. On the motion of Professor Kirk, seconded by Mr Aston, the report of the Carter Bequest Committee was adopted, and the committee discharged. Professor Kirk also moved the following resolution, which was carried:—"That the letter from the City Council be

acknowledged, and that the Council be informed that the Institute, as at present advised, does not regard itself as justified in agreeing to the proviso that it should, at this time, buy a particular mirror and construct and mount a telescope, at very great expense to the Carter Fund; further, that it does not see its way to construct an observatory primarily to house a telescope that is not, whether through gift or purchase, a Carter Memorial Telescope; that the proviso as to representation of the City Council on the body controlling such an observatory as was contemplated is one that the Institute would readily have agreed to; that the City Council be thanked for its consideration of the proposals submitted to it, which proposals the Institute regards as now definitely disposed of.

Fellowship Election, 1932: On the motion of Mr Hudson, seconded by Professor Kirk, it was resolved that two Fellows be elected in 1932.

Correspondence: A reply (23/3/31) from Lord Rutherford of Nelson to the Institute's letter of congratulation was read and received. A letter (12/3/31) from the Danish Acting Consul covering the presentation to the Institute by Dr J. Schmidt, of the "Dana" medal, was received. It was resolved that the medal be placed in the Dominion Museum.

A letter from the Hon. Minister of Finance (1/5/31) regretting the necessity for reducing the Institute's grant was received.

Election of Officers: President, Professor H. W. Segar; Vice-President, Mr B. C. Aston; Hon. Treasurer, Mr M. A. Eliott; Hon. Editor, Professor D. M. Y. Sommerville; Hon. Librarian, Professor D. M. Y. Sommerville; Hon. Returning Officer, Professor H. W. Segar; Managers Trust Accounts: Messrs Aston and Eliott; Representative Tongariro National Park Board, Mr B. C. Aston; Representative Institute of Horticulture, Mr B. C. Aston; Representative Great Barrier Reef Committee, Mr W. R. B. Oliver; Representatives on Wild Life Council, Professor Kirk and Dr Cockayne.

Election of Committees: Research Grants Committee (re-appointed), Dr Hilgendorf (chairman), Professor Speight, Dr Denham, Dr Farr, and Mr C. E. Foweraker.

Library Committee: Re-appointed (Professors Sommerville, Kirk, and Cotton).

Finance Committee: Re-appointed (Messrs Eliott, Aston, Dr Cockayne, Dr Marsden, and the President, ex officio).

Sidey Summer Time Award Committee: Dr Marsden (convener), Professor Easterfield, and Professor Hercus.

Hector Award Committee: Mr Elsdon Best, Mr H. D. Skinner, Mr W. R. B. Oliver (convener).

Votes of Thanks were passed to the President, Dr C. Coleridge Farr; to Victoria University College; to the Press; and to Miss Wood.

Date and Place of Next Annual Meeting to be left in the hands of the Standing Committee.

Travelling Expenses of members to the Board were voted.

PRESIDENTIAL ADDRESS

Delivered at the Annual Meeting at Wellington on 20th May, 1931.

By Dr C. Coleridge Farr, D.Sc., F.R.S., F.N.Z.Inst.

Gentlemen,—

Before I proceed with the remarks I have to make, I would ask you to stand while I refer to some of those who have passed away.

At the last Annual Meeting, held about sixteen months ago, we had with us Mr A. M. Wright, and he and I travelled down by the same ferry steamer that night. On the next evening he was taking part in a dinner to celebrate the formation of a local branch of the Institute of Chemistry, when his end came suddenly and quite peacefully. He just ceased to live. I need not give an account now of his work. He was one of those who formed the connecting link between science and industry. He took a keen interest in the more or less academic operations of our Institute, and at the same time he was a leading authority upon the scientific problems connected with the frozen meat trade. We shall miss him from our midst to-day.

Others to whom I may refer are Mr Carse, of Auckland, Mr A. Philpott, of the Cawthron Institute and Auckland Museum, Mr F. T. Leighton, who acted as secretary of the Institute during Mr Aston's absence in England, Sir Robert Stout, and Lady Hector, who, as the widow of Sir James Hector, was a link between the past history of our Institute and the present time. Sir James Hector was mainly responsible for the early traditions of the Institute, and the solid foundations on which it was built were largely laid by him. One only of our hon. members has, as far as I know, died, viz., Sir W. T. Thistelton-Dyer, late Director of Kew Gardens, whose name is, of course, well known to you all. There is, too, one other to whom—though he was not connected with our Institute—I should like to refer. Lord Melchett, the mainspring of Imperial Chemical Industries, died during the year. As Alfred Mond he succeeded his father, Dr Ludwig Mond, in the management of that great firm of chemical manufacturers, Brunner, Mond, and Co., which later on, by absorbing several smaller concerns, developed under the guidance of Lord Melchett into Imperial Chemical Industries, which is probably the greatest chemical manufacturing organisation that the world has ever seen.

As regards the occurrences of the year, there are one or two events which I should like to refer to.

Change of Title:—

One of these is the change of title, which I suggested last year. I am greatly in hopes that this meeting will authorise your incoming President to take the necessary steps to bring about the suggested change, a change which I venture to think would clothe the Institute with that dignity and distinction which, by its many years of unostentatious work, it has most justly earned. Inquiries which have been made indicate that in the Institute's case there should be no great difficulties, and the steps which must be taken are now known to us.

Notable Celebrations:—

This year is the centenary of three notable scientific events. The first of these is the centenary of the formation of the British Association, and the centenary meeting is being held in London in September, for the first time in the Association's history. It is hard to estimate the influence of this great Association on the world's advancement. Its meetings are of a different nature from those of the more rigidly scientific societies and are attended, as you know, by many who are not active scientific workers, but are intensely interested listeners. This Annual Meeting would seem a fitting opportunity to pass a resolution of congratulation on the work the British Association has accomplished.

Two other occasions which I would like to bring before the notice of the local Institute are those of the birth of James Clerk Maxwell, who was born in Edinburgh on June 13, 1831, and who was the first Cavendish Professor of Physics at Cambridge. The fact alone that Lord Rutherford of Nelson is the fourth of this brilliant band should commend the anniversary of Maxwell's birth to us, but there are other and wider reasons why general notice should be taken of it.

The other centenary is that of Michael Faraday's epoch-making discovery of the induction of electric currents. This, too, has a personal interest for us here and for me in particular, for many of you will remember Sir William Bragg, who was president of the Australasian Association meeting which was held in Dunedin in 1903. Sir William is Faraday's successor, though of course not immediate successor, at the Royal Institution in London, where Faraday's great discovery was made. To me the connection is even more intimate in that Sir William Bragg was one of my early teachers.

These two men, Maxwell and Faraday, were, as you all know, practically the founders of electrical science and electrical engineering as we know it to-day. Faraday's discovery of the induction of electric currents by the movement of magnets is one of the solid foundations of all modern transmission schemes. The other foundation was Oershed's discovery some twelve years earlier of the magnetic effect of an electric current. There can be no doubt that the simple, honest, unostentatious work of these two investigators has had more beneficial influence on the progress of the world than all the bickerings, quarrels and strife, and high ideals and ambitious of parliamentarians and statesmen, though it may be that there are politicians alive to-day who do not know the names of either of them, and I think it is certain there are many who have not heard of both of them. When to these we add the name of Maxwell, that great mathematician who developed theoretically the fertile ideas of Faraday, we have a trinity of investigators whose work for the industrial and scientific progress of the world will always remain. It is well then that their names should be known and honoured. The Faraday Centenary is on August 31.

Earthquakes:—

The deplorable earthquake which happened in February last in Hawke's Bay, focusses our attention once more on these matters. It must be realised—indeed, it probably is realised—that New Zealand, like Japan, is in a region of the earth's surface more liable to such disturbances than some others. We cannot help these things, but as scientific men we can point out what has been already learned, and indicate the steps which should be taken to increase our knowledge. And here I would like to say from this presidential chair that at present, whatever his pretensions may be, no one can predict these disasters. Localities where 'quakes are not unlikely can be indicated, but neither the exact place nor the time can be foretold. There are some who claim to be able to do so, but their claim will not stand the light of scientific examination. Such persons very often do not even know the rudiments of scientific inquiry, and are in themselves very often otherwise ignorant. I do not say they are always charlatans, for I have no doubt that they have in their own minds satisfied themselves they are right, but so are those who claim to be King George V, or some other distinguished person. These claims are not based on exhaustive scientific inquiry, and it is only by these means that the knowledge will come which will enable us perhaps to predict these most disastrous events. That time has not yet come. It quite probably will come in the future—there are some promising indications that it will—but still much has been learned. And one thing that has been learned, and has come out with startling clearness, both in Japan and in Hawke's Bay, is that where the earthquake occurs in thickly-populated districts the resultant fire is more disastrous than the actual 'quake itself. In these days of town-planning, steps can be taken and should be taken to put in fire-breaks, so that the fire, which is sure to start, may find itself checked and unable to spread to other places not already alight.

It is important, too, to keep a watchful eye on the fault movements always taking place. It is unfortunate for New Zealand that the main earthquake line in this country seems to run through the North Island, extending as it does from Hawke's Bay to the West Coast of the South Island.

Since the Murchison 'quake a good many additional seismographs of the latest patterns have been obtained, but so far these have not yet been set up in all cases. I could say a great deal about these matters and other things which have come before me as one of your representatives on the Observatories Committee, but as I understand that difficulties which stood in the way of complete co-operation between the various activities involved are just about to be removed —if they are not already removed—it is unnecessary perhaps to refer more in detail to them. I would, however, strongly urge the most complete co-operation and unity of control, for it is only in this way that progress can be made.

Fellowship and National Research Council:—

Though these questions have been before committees during the year, and recommendations will be made concerning them, definite progress in these respects depends on your discussions to-day. Events which have come before me during the year have more than ever convinced me that there are occasions when the strong consensus of scientific opinion, expressed as it could be by a National Research Council, would be useful. If such a council could be combined with the Fellowship, it would improve the status of both bodies.

The Dominion Museum:—

At last the affairs of the Dominion Museum are reaching finality, and I was exceedingly pleased to receive an invitation to be present at the laying of the foundation-stone of the new building at the Mount Cook site, which took place last week.

Whilst some of us no doubt may regret that the present site cannot be maintained—indeed, I do myself—yet, no doubt, the Mount Cook site will not, even now, be unsatisfactory, and will in time become more suitable, as the Museum and Art Gallery themselves attract a better class of building in the neighbourhood, for a noble pile of buildings is to be erected. I think I may say that the Standing Committee is very gratified with what has been done. The New Zealand Institute receives a very proper representation on the Board of Trustees, and will, we understand, have an even greater influence on the Management Committee of the Museum itself, as distinct from the Art Gallery. The Act provides for two representatives on the Board of Trustees, viz., the president and vice-president, but, very wisely, provision is made for the appointment of deputies in case of inability to attend. In my own case, I have considered that some Wellington resident would in every way be a more suitable representative than myself, and Professor Kirk has very kindly acted for me in this respect. From the number of notices of meetings of the Board of Trustees which I receive, I conclude that the Board is getting to work actively and energetically, and I feel that we may well congratulate the Trustees, and especially Mr Troup, on the progress that has at last been made. May I add, as a resident of another city, that it is not from any want of interest in the Museum that I have asked Professor Kirk to act for me, but from the conviction that this was much the most sensible thing to do.

Financial:—

The financial position of the Institute is a matter of grave concern. I may perhaps be permitted to point out, as indeed I did last year, that the work of the New Zealand Institute is performing a public work in the publication of some of the scientific papers which are read before the local Institutes. I say some, because it is by no means all of the papers which come before the local Institutes which are accepted for publication, but only those which, after passing the critical eye of competent scrutineers, are deemed of sufficient merit for publication. No doubt, more culling can still be done and will

be done, but too drastic cutting down of the size of some publications will react on the scientific work being done, and that in turn will damage the scientific reputation of the Dominion, and also, indeed, hinder its industrial progress. Science is ascertained knowledge, and the scientific publications of a country are a record of observational and experimental ascertained fact, very often regarding the resources of that country. It is undoubtedly the scientific advance of the past 50 years that has been the main cause of the industrial development. For some years past, the Institute has had to draw on the resources of local Institutes, mainly to pay a debt which had been incurred whilst our printing was being done at the Government Printing Office. When other arrangements became possible, we were gradually, with the aid of support drawn from the local Institutes, enabled to reduce the debt, and had practically managed to wipe it out when the present depression came upon us, and we have just been informed that not only has our vote been cut down to half its former value, but also our research grant vote, which we have had for many years, has this year been totally abolished. These things are a serious blow to the Institute's activities, as our resources from the Government have thus been cut down from about £2500 to £750. This covers a grant for general purposes of £1500, and a research vote of about £1000. All of us, of course, recognise the seriousness of the financial depression through which we are passing, and trust it will soon be past. When this takes place, we shall look confidently to the Government to restore us to the position we have occupied so long and, I think, so honourably. We are performing a public service, and have a right to expect sufficient financial aid. The local Institutes are entirely supported by their local voluntary subscriptions, and have their own provincial duties to discharge. The encouragement of science in the district, the establishment of scientific libraries for workers in science, the encouragement and in some cases the actual support of local museums, is their work; the publication of the best of the work done by them is ours. It is not an encouragement to a man if, besides devoting a great deal of time and labour without thought of payment to the elucidation of a scientific question, he also has to pay for the cost of making the results of his efforts known to the world in general. He is, as it were, asked not only to give his knowledge, his energy, and his time to the public without fee, but also to pay the public for the cost of the present. Under such circumstances—if they continue long—the gifts so given, the volume and merit of scientific work done, that is to say, is likely seriously to decline, to the detriment of the culture and knowledge of the Dominion and to its discredit in the eyes of the outside world. I therefore very seriously hope that as soon as these present clouds of depression clear away, the New Zealand Institute's finances may be put on so satisfactory and permanent a footing that it will be unnecessary to continue this improper taxation of local affiliated societies—a taxation, be it said, rendered necessary by the high cost of printing at the Government Printing Office, as we soon discovered when, with Ministerial authority, we were permitted to go into the open market with our work.

The New Zealand Institute Act:—

As was agreed last year should be the case, application was made for certain amendments in the New Zealand Institute Act. A special committee was appointed to consider these, and in due course a Bill to amend the Act was introduced into Parliament. Whilst this Bill was before the House, the valuable suggestion was made that power should be incorporated in it so that apart from the regular Government nominees and members otherwise elected, the Board of Governors itself should be able to add the name of one extra member. It was felt that occasion might arise when it would be most useful to have the advice of someone who was not on the Board, and the claim I am referring to, which was finally incorporated in the Act, gives this power. As this matter had not been before the Board of Governors or the committee, I communicated in writing with the various members of the Board regarding it, and am glad to say the suggestion (which was not my own) was unanimously approved.

It is in consequence of the new Act that we are meeting to-day instead of in January as we have hitherto done, and it is also in consequence of it that we now have a vice-president—the first of whom is Mr Aston. I feel sure you will agree with me that the immense amount of work Mr Aston has done over so many years points him out as a most suitable occupant for the new position.

In conclusion, I would like to thank the various members of the Board for their help during the two years in which I have occupied the presidential chair, and which will terminate in a few hours, and in particular I should like to say how much I have appreciated the cheerful, pleasant, and efficient way in which our assistant secretary, Miss Wood, has put me right in the many places where otherwise I should have gone wrong. May I finally make the suggestion that as, most unfortunately under stress of circumstances, we have had to reduce the remuneration she receives, we should at any rate give her her due and alter her title from assistant secretary to that which she really occupies, namely, secretary. If the word assistant is at all required, which I do not think it is, a much more just title would be assistant president, for without her advice and assistance I fear the affairs of the Institute would speedily become entangled.

ELSDON BEST, F.N.Z.Inst.

Death has deprived New Zealand of her greatest student of Maori lore and culture. Elsdon Best was born in the early settlement of Porirua, near the city of Wellington, in 1856. In 1865, his family moved to Wellington, where, after passing the Junior Civil Service Examination, he entered the office of the Registrar-General. His country and bush upbringing had implanted in him the love of the open spaces, which remained with him through life. One year of office work was enough, and he sought the open air of the Poverty Bay district in 1874. After some years of station life, the opportunity for adventure drew him into the Armed Constabulary at Wellington, from whence armed forces were sent to Taranaki to disperse the gathering of Maori tribes under Te Whiti at Parihaka. Here he was associated with a contingent of friendly Maoris, and one can imagine him sitting by the camp-fire at night encouraging them to unfold tales of their ancient lore. He left the Armed Constabulary after the arrest of Te Whiti and Tohu in 1881, and returned to the East Coast. In 1883, he wandered abroad through Hawaii to California and other States, where he had experience of timber work and ranching. He had many adventures amongst the wild spirits of those parts, but met with no serious trouble, for he never " packed " a gun. The display of weapons was an invitation which was quickly accepted in those regions.

In 1886, Elsdon Best returned to New Zealand. After some years of sawmilling, he went to the newly-opened Urewera Country as an officer of the Lands and Survey Department. He quickly realised that the Tuhoe tribe, in the forest isolation of that region, had retained a greater mass of their ancient culture than the tribes in closer proximity to white settlements. He set to work to record the Native lore and history of the Tuhoe tribe, the Children of the Mist. His interest in local culture broadened out to include the culture of the Maori people. His love for delving into Maori lore became his absorbing interest in life. He earned the confidence of old men who were the repositories of the knowledge of their tribes. Throughout Elsdon Best's later writings there are constant references to Tutaka-nga-hau of Tuhoe and Hamiora Pio of Ngati-awa. These experts, and others, admitted the keen student of another race behind the screen that stands between two cultures. He saw things with their eyes and felt with their feelings. They unfolded to him the intricacies of their spiritual and mental concepts. He learnt their psychology from practical observation and constant association. Out in the open, one of his teachers told him of the sacred name of Io, the one supreme god. When he sought further details of Io in the evening beside the camp cooking fire, a blank curtain descended over the face of his erstwhile vivacious teacher. The sage knew nothing. Later on, under the free expanse of heaven, his teacher turned to Best and said, " Never again mention the name of Io under a roof or near a cooking-fire." And so the student came to know when and how to put questions. During a goodly portion of this period, he lived under canvas and moved camp from time to time to be nearer sources of information that could be tapped. He worked during the day to provide the necessaries of life, but the evenings were devoted

to study, questioning, listening, and recording. Thus in a field camp pitched beside woodland streams or in deep glades of the forest of Tane, there was laid the foundation of that knowledge which subsequently shed an illuminating light on Maori culture and enriched the world's store of information concerning the study of man.

The outstanding feature of Elsdon Best's achievement was that he took up the study of ethnology without encouragement or financial assistance from outside sources. In these days, ethnology is a recognised science taught in universities. Research funds are now more or less available to enable students to conduct investigations in the field. Research funds were not only not available to Mr Best, but he

ELSDON BEST, F.N.Z.Inst.

accepted a mere pittance to keep body and soul together in order that he might continue to live in a locality that had no financial openings, but was rich in the lore which his scientific mind valued above gold and pecuniary advantage. His was the spirit of the true pioneer. His only encouragement was association with kindred spirits such as Colonel Gudgeon, Percy Smith, and Edward Tregear. It was this quartette, under the leadership of Percy Smith, who were responsible for the formation of the Polynesian Society in 1892. Mr Best was a member of the first council of the Society. Later, he served as President; and in the years preceding his death, he was joint Editor of the Journal with Mr J. C. Andersen. He was a constant contributor to the Journal from its very inception.

Elsdon Best was fond of repeating Colonel Gudgeon's advice to him in his early recording days: "Young man, collect information for 20 years and then begin to write." Such advice, though sound,

would not suit the modern student who, after taking a university course in anthropology, dashes off into the field for six to twelve months, and writes a thesis for his Doctorship degree. Though Elsdon Best may not have waited 20 years, certain it is that he had a sound knowledge of his material when he began to write his longer articles on Maori subjects. Curiously enough, his first article in the first volume of the Polynesian Journal, 1892, was on "The Races of the Philippines." His first article in the *Transactions* of the New Zealand Institute appeared in Volume 30, 1897, and was on a subject that he had made peculiarly his own, "Tuhoe Land: Notes on the Origin, History, Customs, and Traditions of the Tuhoe or Urewera Tribes." His shorter articles appeared in the Polynesian Journal, while to the *Transactions* were submitted the longer and more detailed subjects such as "The Art of the Whare Pora," "Maori Eschatology," "Maori Forest Lore," "Maori Medical Lore," and a number of other valuable papers.

After the formation of the Maori Health Service, under the Department of Public Health, in 1900, Elsdon Best was appointed health inspector for the Mataatua Maori Council district, which included his Tuhoe country. By this time, the great work he was doing was recognised. Later, he received the appointment of Ethnologist at the Dominion Museum in Wellington. Though his salary was quite inadequate for a man of his attainment, the position gave him the opportunity of settling down in comparative comfort, with the access to libraries that he needed in order to write up the rich wealth of material he had accumulated. In 1912, his exhaustive monograph on "The Stone Implements of the Maori" appeared as Bulletin No. 4 of the Dominion Museum. This followed on the series inaugurated by Augustus Hamilton, when he was Director of the Museum. Elsdon Best was the first to formulate a terminology for stone adzes of the Polynesian area. His outstanding work was recognised by the New Zealand Institute, which, in 1914, awarded him the Hector Medal "for research work in ethnology." It is characteristic of the modesty of the man that he stoutly maintained that the medal should have been awarded to his colleague, Percy Smith, before himself. Another Dominion Museum Bulletin, on "Maori Storehouses and Kindred Structures" followed in 1916. In 1919, Elsdon Best was elected one of the twenty foundation Fellows of the New Zealand Institute. Whilst his work continued unabated, and manuscript after manuscript was completed, a cessation of printing took place until 1922. In 1922-23, a series of six invaluable Dominion Museum monographs appeared. The Dominion Museum Bulletin series was resumed in 1924, with the first section of "Maori Religion and Mythology," followed in 1925 by a magnificent volume on "The Maori Canoe."

Elsdon Best's writings and his personality had been exercising a profound influence on the inarticulate students of Maori lore who had Maori blood in their veins. Ngata, Pomare, and myself felt that we should do something to carry on the work begun by Best, Percy Smith, and others of the white race. The result was the establishment of the Board of Maori Ethnological Research, with funds to assist research and provide for printing. Elsdon Best was appointed a member of the Board, and served on it until his death. The Board

set to work to print Mr Best's manuscripts as speedily as possible. Though still appearing as Dominion Museum Bulletins, they were printed under the direction of the Board. Thus, in 1925, appeared two further bulletins, "Games and Pastimes of the Maori," and "Maori Agriculture." The remaining numbers of the Bulletin series were "The Pa Maori" (1927), "Fishing Methods and Devices of the Maori" (1929), and "The Whare Kohanga" (1929). Two other works were published as Memoirs of the Polynesian Society; "The Maori," in two volumes, and "Tuhoe," also in two volumes. A smaller form of "The Maori" was printed as a New Zealand Board of Science and Art Manual, under the title of "The Maori as He Was." Before his death, Mr Best was busily engaged on the second part of "Maori Religion and Mythology."

Elsdon Best was widely read, and covered Polynesia and more distant lands in his references and comparisons. His major works, together with the numerous papers in the *Transactions* of the New Zealand Institute, Journal of the Polynesian Society, and other periodicals, form a stupendous contribution for one area by one man. His work throughout maintains the highest standard of reliability, for he was essentially a field worker dealing with first-hand information obtained in a native language which he thoroughly understood. Though he pondered, at times, over striking similarities with ancient Babylon and Sumeria, he never committed himself to any fanciful theories. He was a gifted writer, for he put into English words what Maori orators had told him. While drawing attention to Maori mytho-poetic forms of expression, they flowed through his fingers into his pen. He was honest to a degree, for when he found archaic terms and expressions in old-time songs and chants that his informants could not explain, he recorded the words, but refused to guess at translations. In spite of his wide reputation, he remained a simple, modest, and lovable man, approachable by all. Nothing pleased him more than to interest people in his subject, and assist them in obtaining a true perspective of the race which he had made a lifelong study.

Mrs Best survives her husband. Through all the strenuous years in the Urewera Country, she accompanied him in camp and field. She was the perfect helpmate and comrade, for she was imbued with the same high spirit which brushes aside personal inconvenience and discomfort for the sake of the quest. May the love and affection of her husband's many friends assist in bringing her surcease of sorrow in the House of Mourning.

The reputation of Elsdon Best is established throughout the scientific world. His work forms an imperishable monument to his memory. As long as the race shall endure, men and women of Maori blood will owe a debt to the man who toiled so long and so arduously to record their ancient culture, with its halo of romance and achievement, "that he who runs may read." We shed our tears on the plaza of Death for him whose head rests on the pillow which cannot be removed. The giant totara tree has fallen. The lofty peak of the mountain has been levelled. A horn of the crescent moon has been severed. An open face has passed along the sunset trail of the Broad Pathway of Tane. Te Peehi! Farewell.

TE RANGI HIROA.

New Tertiary Mollusca from New Zealand. No. 2.

By C. R. LAWS, M.Sc., Teachers' Training College, Dunedin.

[*Read before the Otago Institute, 11th November, 1930; received by Editor, 2nd March, 1931; issued separately, 31st March, 1932.*]

UNLESS otherwise indicated the fossils described below have been collected by the writer. He is greatly indebted to Dr H. J. Finlay for assistance in identification, and wishes also to thank Dr W. N. Benson and Dr J. Marwick for the loan of material. In a note at the end of this paper Dr Finlay has compared the Volute faunas of Ardgowan and Target Gully shell-beds, and has discussed some doubtful points relating to certain genera and species of Volutes.

Genus **Trichomusculus** Iredale, 1924.

Type *Modiolaria barbata* Reeve.

Trichomusculus lornensis n. sp. (Fig. 41).

Shell very small, highly inflated, especially anteriorly; beak almost at anterior end, full and strongly curved over; valve angled behind posteriorly from beak, the angle becoming broader and lower towards posterior margin. Dorsal and ventral margins sub-parallel, dorsal one straight, ventral lightly convex over anterior three-quarters and slightly concave at posterior fourth. Posterior dorsal surface (above angle) lightly concave, centre surface of valve flattish. Whole surface covered with concentric striae, some more prominent than others and marking more definite pauses in growth; posterior end covered, from a little in front of the dorso-posterior ridge, with fine radiate riblets, about own width apart and finely crenulating the margin; a few very faint radials immediately under the beak; medium part of shell smooth except for growth lines. Interior not seen as the shell is firmly cemented to a small brachiopod.

Height, 4 mm.; length, 9 mm.; inflation (1 valve), 2·9 mm.

Locality.—Waiarekan tuffs, Lorne, near Oamaru.; outcrop " A " of Marwick. *Trans. N.Z. Inst.*, vol. 56, p. 307; 1926. (Waiarekan).

Type (only specimen) in writer's collection.

Ancestral to *barbata* Reeve, but differs in being more rectangular in outline, not winged posteriorly, fuller at beak and in having length less relative to height. *Barbata* has angulation of valve sharper and its extremity at postero-ventral margin, that of *lornensis* reaching to about the lower third of posterior margin.

This is the first fossil representative of the genus to be recorded from the early Tertiary of New Zealand. *T. barbata* is not uncommon at Castlecliff, but no other occurrence of the genus as a fossil in New Zealand is known to the writer; it is, however, present in the Janjuian of Australia (specimens in the collection of Dr Finlay).

Talabrica nummaria Powell. (Figs. 36, 37).

A description of this shell was originally included in the present paper, but Powell's prior recognition of the species (*Rec. Auck. Inst. Mus.*, vol. 1, No. 2, p. 109; 1931) has made it necessary to suppress the name that had here been given it. This is rather fortunate, for Powell's figures show that the present writer's specimen (also from Nukumaru) is a worn shell and would not have been a good type.

Genus **Semeloidea** Bartrum and Powell, 1928.

Type *S. donaciformis* Bartrum and Powell.

Semeloidea miocenica n. sp. (Fig. 46).

An ancestor of *S. donaciformis*, a Pliocene shell and hitherto the only recorded species of the genus. *Miocenica* is readily separable by reason of its slightly larger size, greater inflation of shell and beak, and fewer and weaker radial corrugations, of which there are three as against five in *donaciformis*; width of grooves less than that of ridges; posterior margin broken away; posterior dorsal margin straight and not arched up; anterior margin relatively higher and more rounded compared with *donaciformis*. In both species the radial sulcations cause marginal crenulations below, but in *miocenica* these are not as pronounced as those of the Kaawa shell, and are wider and shallower. Owing to the fractured state of the shell it has been impossible to remove the matrix to examine the interior.

Height, 6·5 mm.; length, 9·5 mm.; thickness, 2·5 mm.

Locality.—Rifle Butts, Oamaru (Awamoan).

Holotype (single right valve) in writer's collection.

Bartrum and Powell (*Trans. N.Z. Inst.*, vol. 59, p. 158; 1928) located their genus somewhere near *Semele;* but Finlay (*Trans. N.Z. Inst.*, vol. 61, p. 255; 1930) has stated that *Semeloidea* should not be included in the Erycinidae.

Genus **Loboplax** Pilsbry, 1893.

Type *Chiton violaceus* Quoy and Gaimard.

Loboplax ashbyi n. sp. (Fig. 45).

The species is represented by a single intermediate valve only. Valve well arched up, its flanks meeting at an angle of about 90°, strongly beaked behind. Tegmentum narrower in front, slightly lobed at each side behind. Jugal tract of dorsal ridge narrow, widening anteriorly and bordered by elongated, flat-topped ridges running in an antero-posterior direction. Latero-pleural areas sculptured by radially disposed, elongated, flat-topped, low granules. Sinus not deep, but right sutural lamina partly broken away. Insertion plate with one slit nearer posterior end. Internally a widely triangular, transverse callus extends across below beak, grooved along its anterior edge, as a surface of articulation for succeeding valve.

Height, 4 mm.; length, 3·5 mm.; width, 5·5 mm.

Locality.—Shell Gully, Chatton, near Gore, Southland (Ototaran).

Type in writer's collection.

The first fossil representative of the genus to be recorded from New Zealand. Differs at sight from the genotype in the high arch of valve, less definitely differentiated and narrow jugal tract, more prominent beak and different shape of tegmentum.

Named in honour of Mr E. Ashby, who has already described *Callochiton chattonensis* from these beds.

Genus **Zeminolia** Finlay, 1926.

Type *Minolia plicatula* Murdoch and Suter.

Zeminolia fossa n. sp. (Figs. 1, 2, 3).

Shell small, orbicular, very widely umbilicate. Spire equal in height to aperture, angle obtuse. Periphery of body-whorl raised into two thin, sharply elevated keels separated by a deep, narrow channel. Several very faint, broad, low spirals on upper convex surface of whorls. Suture deeply channelled; each whorl attached to upper surface of lower and therefore keel of preceding whorl hidden; whorl rising from suture above at 45° and then descending outwards at angle of 90° to keel below as a lightly convex surface. Axial sculpture present as retracted, bluntly rounded ridges beginning on upper angle around channel of suture and dying out towards keel below. The sutural ridge is therefore nodular. On early post-embryonic volutions the axials descend into channel of suture. Axial sculpture not quite so strong on last whorl. Protoconch of one volution, large, bulbous, smooth, its suture deeply excavated even in earliest stages; ending in an expanding well-marked varix. The next phase of development is represented by $\frac{3}{4}$ of a volution with 5 or 6 coarse spirals about twice own width apart, emerging in the first instance abruptly from aperture of embryo. This is succeeded by the first appearance of 4 or 5 weak axials, followed by rapid axial acceleration. Here only three of the spirals persist, the upper one as a row of weak nodules on axials on flank of sutural channel, but soon becoming obsolete; the second as the strong upper nodular ridge of adult whorls. Base lightly convex, unsculptured, sharply angled around wide, perspective umbilicus, which is spirally lirate within on concave descending portion. Circum-umbilical angle crenulated. Aperture quadrate, interior nacreous.

Height, 2·9 mm.; greatest diameter, 4·5 mm.

Locality.—Greensands about a mile below Wharekuri, left bank of Waitaki River (Ototaran).

Holotype and a very juvenile paratype in writer's collection.

Finlay (*Trans. N.Z. Inst.*, vol. 57, p. 360; 1926) has separated the Neozelanic Minolioids into two series based primarily on embryonic characters. For those with "a tiny inconspicuous embryo" as well as other distinctive shell characters he has provided the genera *Antisolarium* and *Conominolia,* while *Zeminolia* and *Zetela* have a "disproportionately large and bulbous embryo and different umbilicus," that of *Zeminolia* being very wide and perspective. The new

shell has been compared with *M. plicatula* (the genotype) and is referred to *Zeminolia* as an ancestor of *plicatula* on account of its wide umbilicus and closely similar embryonic features. Microscopic examination shows that the smooth embryo of *plicatula* is marked off from the rest of the shell by a varix very similar to that of the shell just described, but less prominent. *Plicatula* differs in having whorls much more rounded, strong, regular, evenly-spaced spirals, very weak, but similarly disposed axials, flat shoulder and suture not channelled. The sculpture of the new species, however, can reasonably be expected to be bridged by connecting links with that of the Recent shell.

Genus **Astræa** Bolten, 1798.

Type *Trochus imperialis* Gmelin = *heliotropium* Martyn.

Astræa stirps n. sp. (Figs. 4, 7, 11).

Ancestral to *heliotropium* Martyn. A large, conic shell carrying prominent spines along sutures of all post-nuclear whorls and around periphery of body-whorl, which has a strong keel that expands at intervals of about an inch into heavy, rounded, obliquely costate spines. These originate as an overfolding of the shell substance in the direction of growth. From the rear of the folds the large, hollow spines protrude, directed forwards, proximally resting on upper part of whorl below, but distally free, and at least an inch in length on penultimate whorl. The overfolded part runs forward as far as the root of the next spine and then obliquely towards suture above, so that the sculpture is in sections and an apparently new set of spirals emerges from beneath each fold. *Heliotropium* has 18 spines on body-whorl; the new species 8 or 9. The sculpture consists of spirals in two series, both trending obliquely at a low angle across whorls. The primary spirals (8 or 9 per whorl) are granular, not scaly as in *heliotropium*, the granules spaced about their diameter apart, the spirals separated by interstices equal to their own width. The earlier whorls have primaries only, but on the ante-penultimate whorl secondary spirals first appear in the interstices, emerging abruptly from beneath one of the folds; at first one and later two. On penultimate whorl the width of interstices becomes greater than that of the primaries, and the secondaries are now three in number. The primaries are becoming weaker, less regular, wavy, and their granules weak and often spaced more widely, while the secondary sculpture is a good deal more noticeable. This is but a transition stage, for on the body-whorl the primaries are almost obsolete, the whole surface now sculptured by wavy, closely nodular secondaries. Whorls fairly evenly convex, flattened above; but those of *heliotropium* are more shouldered. *Heliotropium* has a wide, perspective umbilicus; but the new species has the umbilicus partly covered by reflection of inner lip. Convex outer zone of base with 5 or 6 low, wide, faintly nodular spirals, interstices and spirals alike covered by secondaries; inner excavated zone descending to umbilicus strongly grooved by about 12 sharp, obliquely raised, curved ridges which represent earlier growth-reflections of inner lip. Height of spire greater than that of aperture. Protoconch missing. Operculum (young and

adult ones from band 6B, Clifden) similar to that of a Pliocene specimen of *heliotropium* from Castlecliff; oval, with excentric nucleus; outside smooth. Flaking around edges of adult specimen shows up minute, flexuous, divaricating spirals crossing growth lines at right angles; a well-marked ridge near to and concentric with outer margin of inside of operculum. (Fig. 5).

Height, 67 mm.; width, 75 mm.; height of spire, 37 mm.

Locality.—Clifden, Southland. Collected from bed B on left bank of river, equivalent to the basal beds of band 7 on right bank (Hutchinsonian).

Type (collected by Mr F. J. Turner) in writer's collection. Two paratypes from band 6A in collection of Dr H. J. Finlay.

This is the second fossil species of *Astræa* from New Zealand, its companion, *A. bicarinata* Suter (*N.Z. Geol. Surv. Pal. Bull.* No. 5, p. 6; 1917) being a Miocene shell from the shell-bed at the base of the Pareora beds, Trelissick Basin, Canterbury. In contrast with *A. stirps* it is a smaller shell with a bicarinate body-whorl and less evident fine lirae between the coarser sculpture.

A. hudsoniana (Jonston) from the Table Cape beds of Tasmania, seems to be intermediate between *heliotropium* and the species just described. It agrees with the former in general shell form, in having numerous spines and open umbilicus, but comes closer to the new species by reason of the granular character of its spiral sculpture. In the topotype examined, however, one of the spirals on the base and another on the upper surface of the last whorl, are distinctly scaly.

A large specimen of *A. heliotropium* from the Pliocene beds at Castlecliff, Wanganui, is figured for comparison (Figs. 9, 12).

Genus **Notoacmea** Oliver, 1915.

Type *Patelloida pileopsis* Quoy and Gaimard.

Subgenus **Parvacmea** Oilver, 1915.

Type *A. daedala* Suter.

Notoacmea (Parvacmea) chattonensis n. sp. (Fig. 47).

Shell very small, oval, elevated, apex at about anterior fifth. Sculpture of numerous fine, closely beaded radials (preserved only on posterior). Microscopic incremental lines present. Anterior slope concave immediately below apex, thereafter straight; posterior slope lightly convex, flatter on top behind apex; margin sharp; radials faintly traceable within.

Height, 1 mm.; length, 1·8 mm.; width, 1 mm. (Holotype).

Locality.—Shell Gully, Chatton, near Gore, Southland (Ototaran).

Type and a number of paratypes in writer's collection.

Distinguished from *P. nukumaruensis* Oliver, the only other Tertiary species, by its concave anterior slope, presence of definite radial sculpture and smaller size.

This record and that of *Loboplax ashbyi* described above emphasize further the shallow water facies of the Chatton deposits.

Genus **Cheilea** Modeer, 1793.

*Type *Patella equestris* Linné.

Cheilea plumea n. sp. (Figs. 34, 35).

Shell small, fragile, almost circular in outline, elevated at apex; posterior slope convex at first, flatter towards margin; anterior end concave immediately below apex, thereafter faintly convex; apex very near anterior, prominent and curved over. Surface covered with fine, flexuous growth-lines, some of which towards margins are strong concentric ridges. Fine, wavy radial striae over whole surface, on the average about own width apart. Distally these striae are not so regularly radial, but cross the successive growth sections obliquely and at varying angles for each section. Margin smooth internally, but deceptively rudely crenate when viewed dorsally. Internal appendage long, regularly convex in front, not spread widely; each lateral horn of appendage traversed externally and medially by a low, rounded ridge, becoming obsolete towards distal end of convex stem of appendage.

Height, 4 mm.; diameter (approximate), 12 mm.

Locality.—New road cutting about half a mile behind racecourse, Clifden, Southland. The equivalent of horizon 7C (of the beds on the river).

Type (sole specimen) in writer's collection. Collected by Mr F. J. Turner.

This adds another genus to the fauna of New Zealand. It has, however, been recorded from Australia by Hedley (*P.L.N.S.W.*, 48, pt. 3, p. 309; 1923), who has discussed the Austral form under the name *Cheilea undulata* Bolten. It has not been recorded as a fossil from Australia or from Java by Martin, but has been found in the Miocene of Jamaica by Woodring. No Recent specimen has been available for comparison, but it is improbable that the Hutchinsonian species here described is the same as a Recent form. It is very interesting to find this definitely tropical genus turning up in the Tertiary of New Zealand.

Genus **Oniscidia** Swainson, 1840.

Type *O. cancellatum* Sowerby.

Oniscidia finlayi n. sp. (Figs. 6, 10, 13).

Shell of moderate size, spire low, angled at about 90°, and $\frac{1}{5}$ length of shell. Protoconch (Fig. 44) pointed, of $2\frac{1}{2}$ to 3 smooth convex turns, nucleus minute; earliest sculpture consists of distant axials extending across whole width of whorl; later post-embryonic whorls angled above middle, axials dying out on the concave shoulder before reaching suture above; suture undulating over fairly strong, sharp axials, placed about twice own width apart; 3 to 4 low, wide spirals on shoulder; one strong one below periphery giving rise to a

*See Woodring, *Carnegie Inst. Wash. Pub.* No. 385, p. 374; 1928.

second row of nodules where it crosses the axials. Eleven strong, flat spiral cords on body-whorl, nodulating the axials, of which there are 11 also. Whole surface covered by fine, vertically raised axial lamellae, indicating growth stages, on shoulder antecurrent towards suture, and about 2 per mm. on the flat-floored interaxial spaces, but densely packed together on axials themselves. Aperture long, oblique; angled behind; interior canal short, open, fairly wide. Outer lip very thick, reflected; 4 strong, evenly spaced denticles along middle third of its length. Inner lip as a heavy callus spread widely over body-whorl and almost on to dorsal surface on neck of canal; but soon rapidly descending over fasciole to end in a sharp beak. About 10 unevenly spaced denticles on pillar, almost outside aperture, and indications of a second fainter row above and behind. Callus of inner lip merges posteriorly into thickened outer lip; but junction is channelled by a canal extending from angle within the aperture. The mass of callus here stands free of whorl and ascends to level of plane of suture of penultimate whorl.

Height (holotype), 40 mm.; spire, 8 mm.; diameter, 25 mm.

Locality.—Clifden, Southland. Holotype from left bank of river, bed " C " equivalent to base of 7 on right bank (Hutchinsonian). Two paratypes (one in collection of Dr H. J. Finlay) from horizon 6B (Hutchinsonian).

Holotype and a fragmentary paratype in writer's collection.

Powell and Bartrum (*Trans. N.Z. Inst.*, vol. 60, p. 428; 1929) were the first to record this genus in the fauna of New Zealand by describing *Morum (Oniscidia) harpaformis*, a member of their very interesting Tertiary (Hutchinsonian) molluscan fauna from Oneroa, Waiheke Island. The present shell is so obviously distinct from the Waiheke one that comparison is unnecessary. The type of *Morum* is *M. oniscus* Gmelin, and the Clifden shells agree better with *M. cancellatum* Sby, the type of *Oniscidia*. *O. finlayi* looks very like the figure of *Morum domingense* Sow. (*U.S. Nat. Mus. Bull.* 90, p. 85; Pl. 12, Fig. 28; 1915), from the Oligocene of Florida; the sculpture is almost a replica, but the aperture seems much narrower, and moreover Dall places the American shell in the section *Herculea* Hanley (G.-T.: *M. ponderosum* Hanley), characterised by a deep posterior notch to the aperture.

This again is a tropical genus, quite foreign to New Zealand's present climate.

Named in honour of Dr H. J. Finlay, of Dunedin.

Genus **Euspinacassis** Finlay, 1926.

Type *E. pollens* Finlay.

Euspinacassis emilyae n. sp. (Figs. 14, 15).

Shell fairly large, not of heavy build for its size, spire whorls with a row of tubercles at angle somewhat above middle; body-whorl with 4 rows of tubercles, those of the lowest row very weak and soon becoming obsolete towards outer lip; 11 in topmost row.

Tubercles project vertically and show tendency to be laterally compressed. Whole surface covered by close spiral cords, the last six on the base (below last row of nodules) more regular and prominent and ornamented with spiral lines. Spire about half the height of the aperture. Spire whorls lightly concave both above and below the angle; a distinct concavity between tubercles in first two rows on body-whorl. Suture slightly undulating over hidden row of tubercles, appressed and margined below by a narrow swollen band. Outer lip thickened, reflexed, and carrying 8 or 9 denticles within, distinct in front, but becoming faint posteriorly. Inner lip spread as a wide and thick callus (not as thick as that of *muricata* Hector) almost completely covering nodules and reaching on to shoulder between tubercles of top row. Callus plate sunken over umbilicus, but rising anteriorly to surmount the low, rounded ridge on the fasciole. In *muricata* the callus plate is flat. Pillar with 3 or 4 small, irregular plaits below. Fasciole almost completely covered ventrally. A sharp keel behind separates it from the wide, deep groove leading to the umbilicus. In *E. muricata*, as the pillar is more erect and its base a good deal more twisted, the fasciole is relatively wider when seen laterally and the groove behind much narrower. Further, in the Pakaurangi Point species this groove widens posteriorly, whereas in the new species the channel becomes slightly narrower towards the umbilicus.

Height, 55 mm.; diameter, 36 mm.

Locality.—Ardgowan shell-bed, Oamaru (Awamoan).

Type in writer's collection.

Finlay (*Trans. N.Z. Inst.*, vol. 56, p. 231; 1926) provided a new genus, *Euspinacassis*, to include *pollens* Finlay, *muricata* Hector, and *grangei* Marwick; to these must be added *E. multinodosa*, since described by Powell (*Trans. N.Z. Inst.*, vol. 59, p. 634; 1929). In the same paper (p. 636) Powell discussed the generic position of *grangei* Marwick, and for reasons advanced preferred to locate this shell in *Xenophalium*; but Dr Finlay and Dr Marwick consider that for the present it is better left in *Euspinacassis*.

A topotype of *E. muricata* (Hector) is figured for comparison (Fig. 16).

Named in honour of my mother.

Genus **Magnatica** Marwick, 1924.

Type *Polinices planispirus* Suter.

Magnatica powelli n. sp. (Figs. 38, 39).

Shell large, ovate; spire very low, whorls four; suture tangential; growth-lines sinuous above, but soon straighten out; faint spiral lines and bands of varying width, low and flat, over whole whorl; funicle almost obsolete; umbilical thread distant; umbilicus bounded by a distinct angulation arising below and sweeping around to enter umbilicus below parietal callus.

Height, 39 mm.; diameter, 40 mm. (Holotype).

Locality.—Ardgowan shell-bed, Oamaru (Awamoan).

Type and several paratypes in writer's collection.

Very close to *planispira* (Suter), but with less elevated spire and later whorls embracing earlier ones a good deal more. *Planispira* is typically a taller, less oblique shell with body-whorl much less convex above periphery. This greater fullness of the body-whorl between the plane of the suture and a parallel plane passing through the top of the umbilicus readily distinguishes the Ardgowan shells from *planispira.* For comparison of the two species, see Figs. 39, 40.

The low, flat spire of *powelli* separates it at sight from *fons* Finlay.

Finlay (*Trans. N.Z. Inst.*, vol. 61, p. 59; 1930) has pointed out the differences in umbilical characters between *Magnatica* and *Spelaenacca.*

Named after Mr A. W. B. Powell, of Auckland.

Genus **Metamelon** Marwick, 1926.

Type *Miomelon clifdenensis* Finlay.

Metamelon prominima n. sp. (Fig. 25).

Shell small, elongately narrowly ovate; spire about $\frac{5}{8}$ height of aperture, outlines straight, conic; nucleus missing; whorls about $4\frac{1}{2}$; periphery very slightly below middle, outline faintly convex below; shoulder straight towards suture, lightly depressed immediately above periphery; body-whorl regularly convex below periphery, but outline straight towards fasciole, which is strong and raised. Body-whorl smooth; spire whorls, though partially decorticated, show faint closely spaced axials, extending over whole whorl and retracted below. Close spiral striae present on last two whorls. Aperture long and narrow; anterior canal wide, notch only moderate; outer lip thin, sinuous, sharp; inner lip spread moderately; columella with 5 plaits, the strongest being second from behind, all oblique, but anterior plaits progressively more oblique than those behind.

Height, 38 mm.; diameter, 12·5 mm.

Locality.—Ardgowan shell-bed, Oamaru (Awamoan).

Type in writer's collection.

M. minima Marwick has probably been derived from this species by a further straightening out of shoulder and suppression of axial sculpture.

Metamelon informis n. sp. (Fig. 26).

Shell rather small, thick and solid for its size; spire just over half height of aperture; apex and earliest whorls missing; shoulder first appears on antepenultimate whorl, more excavated than in *reverta,* but not so deep as in *clifdenensis;* periphery nearly two-thirds above lower suture. Axials fairly strong, persisting from suture to suture, though not so well marked on shoulder, slightly nodular on periphery, widely spaced (set twice own width apart);

axials 10 on body-whorl as against about 16 in *reverta*; they extend halfway from periphery to fasciole as quite distinct ridges, but die out quite early in *reverta*. Aperture well notched in front; columella plaits 4, more horizontal behind.

Height, 46 mm. (approx.); diameter, 17 mm.

Locality.—Ardgowan shell-bed, Oamaru (Awamoan).

Type (unique) in writer's collection.

Obviously developed from *reverta* by decrease in number, but increase in prominence of axials.

Metamelon patruelis n. sp. (Figs. 17, 18).

Shell rather small, light of build, spire two-thirds height of aperture, conic, nucleus smooth and with high spike. Post-embryonic whorls 4½. First whorl below nucleus with almost vertical, flat sides; succeeding whorls lightly convex; a slight sub-sutural depression arises on third whorl, and on next and later ones forms a concave shoulder; the periphery somewhat above middle of whorl. Axial sculpture not prominent; practically absent from body-whorl of holotype except for faint indications of low nodules on periphery, but seen more distinctly on a paratype; axials of early whorls (16 in number) blunt, only faintly nodular, extending across the whole whorl; growth lines flexed posteriorly. Body-whorl convex below shoulder, contracting late but rapidly, constricted before reaching the fairly strong fasciole. Aperture deeply notched anteriorly; inner lip moderately spread over whorl; columella with 5 plaits, topmost horizontal, others becoming progressively more oblique below.

Height, 47 mm.; diameter, 18 mm.

Locality.—Ardgowan shell-bed, Oamaru (Awamoan).

Type and several paratypes in writer's collection.

This species has affinities with *inermis* (Finlay) on the one hand, and with *reverta* (Finlay) on the other. Its weak development of axial sculpture relates it to the former. It agrees very closely in outline and build with *reverta*, but differs in having axials less developed, fewer in number, and not persisting as prominent nodules on last whorl.

Genus **Spinomelon** Marwick, 1926.

Type *Lapparia parki* Suter.

Spinomelon henryi n. sp. (Figs. 22, 23).

Shell large, solid. Spire turreted, a little less in height than aperture. Early whorls convex, but they soon develop a shoulder which later becomes concave and prominent. Whorls angled at middle; axials numerous, curved, twice own width apart, 16 on later whorls and about 20 on earlier ones; axials thin, narrow, extending from suture to suture of earlier whorls and there not nodular; nodules first develop on antepenultimate whorl and become progressively more prominent; with the appearance of nodules the shoulder becomes

more excavated and the axials crossing it weak, almost obsolete on shoulder of last whorl. Axials of body-whorl die out at about a third of the distance from angle to anterior end. Body-whorl cylindrical behind, later contracting slowly to neck. Outer lip broken away; inner lip as a thick pad ridged along outer border, at first descending obliquely from posterior angle of aperture and then vertically down and over fasciole to beak; columella with 5 thick folds more horizontal posteriorly; aperture long and probably moderately wide. Apex missing.

Height, 107 mm.; diameter, 35 mm.

Locality.—Clifden, Southland, horizon 6B (Hutchinsonian).

Type and juvenile paratype in writer's collection.

Named in honour of my father, Dr C. H. Laws, of Auckland.

Spinomelon otaioensis n. sp.

The material on which this species is founded consists of one shell, of which the lower half of the body-whorl is missing. The axial sculpture aud shape of whorls is almost a replica of that of the preceding species, except that the axials are fewer in number, more widely spaced, and perhaps somewhat sharper, and the nodulations appear a little earlier. On the shoulder the axials are more nearly vertical, whereas those of *henryi* are a good deal more oblique (antecurrent upwards). *Otaioensis* looks adult, and therefore is a smaller species and of lighter build than the Clifden one. Axials 15; *henryi* (same stage) 20. Apex of two smooth turns, nucleus caricelloid.

Height, 70 mm.; width, 25 mm. (dimensions estimated).

Locality.—Blue Cliffs, South Canterbury, blue sandy clays above limestone (Hutchinsonian).

Type in writer's collection.

The above two species are apparently allied to *A. residua* Finlay (see note by Dr Finlay at end of this paper) in their possession of numerous, narrow axials reaching across whole width of spire whorls, but obsolete on shoulder of later part of last whorl, though they differ in that the later whorls are most prominently angled. *A. whakinoensis* Marwick, a Pliocene species, is a less slender shell with a wide body-whorl and a very strong fasciole; it has the whorls angled above and not at the middle, and a thinner but wider callus to inner lip.

They are apparently on a different line of Spinomelon from the group centred about *S. parki* (Suter), and are distinctive in the great number of axials sharply nodulated at periphery, well excavated shoulder and angulated whorls. They are obviously congeneric, and bear strong resemblance in many respects to *Alcithoe*, but the caricelloid nucleus of *otaioensis* has made it necessary to locate them in *Spinomelon*.

As the Blue Cliffs shell was collected after this paper had been completed, a figure will be included in the next of this series.

Genus **Alcithoe** H. and A. Adams, 1858.

Type *Buccinum arabicum* Martyn.

Alcithoe separabilis n. sp. (Fig. 24).

Shell of moderate size. Spire conic, about three-fifths height of aperture. Nucleus scaphelloid and of $2\frac{1}{2}$ smooth turns; $5\frac{1}{2}$ post-embryonic whorls, earliest lightly convex, axially costate, the costae narrow, about twice own width apart, and reaching from suture to suture. Later whorls slightly angled about middle, and shoulder a little excavated on last two. Axials begin to develop nodules at periphery on antepenultimate whorl. Nodules become laterally compressed and sharp on later part of body-whorl; 12 axials on body-whorl, 14 on spire whorls; almost obsolete on shoulder of last whorl, extending below periphery and dying out about one-third of distance towards anterior end. Aperture long, narrow, sides parallel; outer lip broken away; inner lip a thin glaze spread fairly widely over whorl; columella with 5 plaits as thin, sharply raised lamellae, spaced equally and all parallel, decreasing in strength from second anterior one; anterior canal wide; fasciole sunken. Spiral striation over whole surface with a number of spiral bands below shoulder of last whorl.

Height, 80 mm.; width, 31 mm.

Locality.—Ardgowan shell-bed, Oamaru (Awamoan).

Type in writer's collection.

Allied to *A. lepida* Marwick from the same locality, from which it is distinguished, however, by greater size, excavated shoulders to later whorls, more swollen body-whorl and greater excavation of base, much more widely spread inner lip, and the nature and arrangements of the pillar plaits.

Genus **Falsicolus** Finlay, 1930.

Type *Fusinus kaiparaensis* Suter.

Falsicolus corrugatus (Marshall). (Fig. 28).

1918. *Fusinus corrugatus* Marshall, *Trans. N.Z. Inst.*, vol. 50, p. 264, pl. 22, figs. 9, 10.

Through the courtesy of Dr J. Marwick, the writer has been able to examine the material on which this species was founded, consisting of two shells, both figured, but neither designated as type at the time of description. The more complete though somewhat smaller specimen figured by Marshall (*Trans. N.Z. Inst.*, vol. 50, pl. 22, fig. 10; 1918) is therefore now selected as lectotype; it is refigured here (Fig. 28) for ease of comparison with a new, closely allied species to be described below.

Finlay (*Trans. N.Z. Inst.*, vol. 61, p. 261; 1930) has revised the New Zealand shells that have been referred to the genus *Fusinus.* In the absence of material he hesitated to make a definite location of this species; but stated that it seemed to resemble *Fusus dictyotis* Tate from the Balcombian of Australia, which has a true *Colus* protoconch, and for this reason he placed it for the time being in *Colus s. l.*

Examination of the type material, however, shows that *corrugatus* has not the paucispiral, globose apex of *Colus* (Fig. 43), but a polygyrate, pointed protoconch (Fig. 42), so that it falls into *Falsicolus* Finlay, and the name *Colus* now disappears from New Zealand lists.

Falsicolus inurbanus n. sp. (Figs. 27, 29).

Close to *corrugatus* at first sight, if one judges by Dr Marshall's figure and description, but comparison with the types shows *corrugatus* to be more slender, and to have fewer axials and more equal keels on spire whorls. The Pakaurangi shells look adult, and therefore the species is smaller than the Clifden one here described. Protoconch missing; 10 rounded axials on body-whorl (7 in *corrugatus*). The arrangement of the cords on the shoulder provides the best means of separating the two species. *Corrugatus* has two of the five shoulder cords stronger, the strong and weak alternating with one another; but those of the new species (5 or 6 in number) are equal and all moderately strong. In both species the spirals are a good deal coarser below the periphery and thicken in surmounting the axials, while the peripheral cord itself becomes compressed on the axials to form tubercles, which are flatter and more prominent in the Clifden shells. Below peripheral cord of *corrugatus* there are about 12 thick cords with an interstitial fine spiral between each pair; 10 thick cords (in places scaly) in the new species with intervening weaker ones; but the fifth and seventh below periphery of last whorl are almost obsolete, so that the sixth stands out as a well marked ridge separating the two wide spiral channels, caused by suppression of the cords on either side. Aperture angled behind and drawn out anteriorly into a moderately long canal. Outer lip broken; inner lip as a thick callus over excavation below body-whorl, its outer edge standing clear of whorl; callus reaching suture above.

Height (holotype), 44 mm.; of aperture plus canal, 25 mm.; width, 23 mm.

Locality.—Clifden, Southland. Holotype from horizon 6B (Hutchinsonian); two paratypes from left side of river, bed A = 6C (Hutchinsonian).

Type in writer's collection.

Falsicolus semilevigatus n. sp. (Fig. 33).

A large, tall-spired, relatively narrow shell intermediate between *F. eoaffinis* Finlay and *F. excellens* Finlay; but the height and angle of the spire, weaker and closer spiral sculpture, and less prominent peripheral tubercles show that it is more nearly related to the former. In his generic diagnosis, Finlay states that there are two series of species based on axial sculpture, one in which there is " a progressive development of heavy axial knobs on periphery "; another showing a " progressive obsolescence of axial sculpture, the later whorls having only spirals." Probably the two series are intimately related. The present shell has affinities with those of the first series, for the first five whorls are entirely devoid of axials and are smoothly rounded

in outline. The axial sculpture, which appears towards the end of antepenultimate whorl, produces only low, faint corrugations not reaching either suture; but the whorls now become angled and the periphery set with low blunt tubercles about their own width apart and 11 per whorl. Whole surface covered with fine, regular spirals, 13 on shoulder, 7 below periphery; below shoulder on spire whorls and over entire surface of body-whorl spirals stronger and about twice their own width apart; interstitial threadlets here and there developed, seen best below shoulder of last whorl. Suture strongly clasping, especially on last whorl, which descends vertically from suture to shoulder. Whorls lightly excavated on shoulder, straight below, but on body-whorl shoulder is distinctly angled just below suture. Inner lip spread with a thin glaze; outer lip dentate from beginning of canal to angulation at periphery. Aperture deeply and narrowly channelled behind.

Height of spire, 35 mm.; of aperture, 24 mm.; width, 31 mm.

Locality.—Ardgowan shell-bed, Oamaru (Awamoan).

Type (single specimen) in writer's collection.

Although this genus is not uncommon at Clifden, the present species seems to be the first recorded from the Awamoan beds at Oamaru, the Fusinids already found there belonging to *Coluzea.*

Genus **Clifdenia** n. gen.

Type *Clifdenia turneri* Laws.

A large, handsome, volute-like member of the Mitridae, with a long, tapering spire; body-whorl swelling rapidly below suture, but soon narrowing off towards anterior. Whorls more convex than is typical of the large Mitras; suture slightly clasping; columella long, straight, oblique, with four plaits well within aperture, posterior two prominent, anterior one indicated by slight swelling on pillar; outer lip thick and showing tendency to reflection; inner lip spread widely in volute-like fashion by shining callus, sweeping from posterior angle of aperture well out across whorl and then vertically down over fasciole, as in *Spinomelon.* Aperture longer than spire (not typical in *Mitra*), thus further giving the shell at first sight the appearance of a Volute. Whole surface covered by fine, dense, sinuous growth-striae retracted above and slightly antecurrent below on spire whorls. Towards anterior of body-whorl, growth-striae sweep laterally to cross fasciole much as in *Alcithoe.* Shell without sculpture except for a few faint spirals just below suture on lightly concave part of whorls.

Clifdenia turneri n. sp. (Figs. 30, 31, 32).

Whorls convex but straighter below periphery, which is high, about a quarter of the distance from upper suture; body-whorl considerably swollen. About 6 faintly raised spirals just below suture, 1 to 1½ times their own width apart. Outer lip well retracted behind in conformity with the backward sweep of the growth-striae. See also generic characters above.

Height, 152 mm.; width, 45 mm.; height of spire, 66 mm.

Locality.—Clifden, Southland, horizon 6B (Hutchinsonian).

Holotype (unique) in writer's collection.

This shell dwarfs all hitherto recorded Neozelanic members of the Mitridae, being as large as the tropical Mitrarias. It is distinctive in its peculiarly Volutid general appearance. The decrease in size of the pillar plaits anteriorly demonstrates its Mitrid relationships, and as the combination of characters given above in the generic diagnosis renders it impossible to include it naturally in any of our existing genera, the new genus, *Clifdenia,* has been created for it.

The large Recent Mitras mostly have a deep posterior notch and altogether different facies. The large, slender Tertiary forms with long canals are usually characterised by predominating spiral ridges (as in *Tiara* Swainson); the Australian and New Zealand early Tertiary *Diplomitra* Finlay has somewhat the same smooth surface, but is much smaller, has fewer pillar plaits, and has a true Mitrid, not Volutid, habit.

Apical fragments of a related species from the greensands at Wharekuri are in the collections of Dr Finlay and of the writer.

Named in honour of its discoverer, Mr F. J. Turner, M.Sc., of the University of Otago.

Genus **Cominella** H. and A. Adams, 1853.

Type *Buccinum maculosum* Gmelin.

Subgenus **Acominia** Finlay, 1926.

Type *Buccinum adspersum* Bruguière.

Cominella (Acominia) kereruensis n. sp. (Figs. 19, 20).

Ancestral to the Recent *adspersum,* which it resembles quite closely. A dozen or so specimens were collected, and these show even a wider range of variation in strength of fasciole development than does the Recent shell. The heaping up of the body-whorl posteriorly, so well shown in the adults of *errata* Finlay and of *ridicula* Finlay, occurs sporadically in the adults of both *adspersum* and the new species, though not to so marked a degree, whilst on the other hand in several specimens the body-whorl attains its greatest width halfway between suture and anterior end, somewhat as in the subspecies *nimia* Finlay, from Chatham Islands. Regular nodules may persist on to the penultimate whorl or become obsolete as early as the third post-embryonic whorl. A large series of shells of *A. adspersum*, from Takapuna, Auckland, shows a similar but not quite so marked variability in the incidence of nodular cessation.

The following separative characters serve to distinguish *kereruensis* from the Recent genotype. In the former there are fewer axials per whorl (11 on antepenultimate whorl as against 13 to 14 in *adspersum*); axials larger and more nodular, not persisting so definitely to suture below; spiral cords separated by grooves equal to or greater than own width (grooves much narrower than cords in *adspersum*); channel behind fasciole weakly developed so that body-whorl is less contracted in front and outline is almost straight below periphery.

Height (holotype), 57 mm.; width, 33 mm.; height of aperture, 34 mm.

Locality.—Kereru, Hawke's Bay (Nukumaruan).

Holotype and several paratypes in writer's collection.

C. facinerosa Bartrum and Powell (Pliocene beds at Kaawa Creek) is a smaller, more strongly inflated shell, not so tall, spire much shorter (½ height of aperture plus canal). It has more prominent spiral cinguli on body-whorl, and apparently lacks the axial sculpture of *kereruensis.*

C. hendersoni Marwick, from North Taranaki, is a good deal more squat, the last whorl considerably embracing earlier ones so that spire appears very low; but Dr Marwick remarks (*Trans. N.Z. Inst.*, vol. 56, p. 323; 1926) that this feature is subject to considerable variation. It has a more prominent fasciole.

Genus **Eucominia** Finlay, 1926.

Type *Buccinum nassoides* Reeve.

Eucominia marshalli n. sp. (Fig. 21).

Shell fairly small, axially costate and finely spirally striated. Spire elevated, greater than height of aperture. Apex moderately large, dome-shaped, of about 2 volutions; axials represented by large, blunt nodules around periphery, not definitely extending to either suture, obsolete over most of body-whorl, 9 on penultimate whorl; interstices about twice width of axials; regular spiral lines over whole surface, visible mainly as colour bands, not as raised cords; about 24 on body-whorl, 12 to 14 on penultimate whorl; whorls bluntly angular at about upper third; shoulder concave, whorls lightly convex below; suture distinct, whorls clasping. Aperture sharply angled behind and deeply notched anteriorly; outer lip thin, sharp, sinuous; inner lip as a slightly raised callus; pillar arched above, straight below; columella groove present. Fasciole prominent.

Height, 19 mm.; diameter, 9·5 mm.

Locality.—Blue Cliffs, South Canterbury; sandy clays above limestone (Hutchinsonian).

Type (the only specimen) in writer's collection.

The fewer and blunter axials at once distinguish this species from *elegantula* Finlay. *Ellisoni* Marwick, from Chatham Islands, is a larger shell lacking the nodules and with a broad subsutural swelling, while *bauckei* Marwick, also from Chatham Islands, has early whorls a good deal more sharply angled, ribs strong and persisting from suture to suture. The Awamoan *intermedia* (Suter) is a larger shell with flatter whorls, weaker nodules and raised spiral sculpture. *E. nana* Finlay, which is perhaps the nearest relative, is characterised by numerous definitely raised spirals and sharper axials, which are more elevated and more numerous (12 per whorl); and has whorls much more clasping at suture.

Collected by Dr P. Marshall.

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NOTE ON THE ARDGOWAN VOLUTES.

By DR H. J. FINLAY.

The collections made by Mr Laws at the Ardgowan shell-bed have proved very interesting. Apart from several new species, he has obtained numerous new records of known forms in this locality, including some rare shells previously known only from the type or a couple of specimens. It has thus been possible to settle several debated points; Mr Laws will remark on some of these in future papers, and for the present attention is drawn merely to the Volute fauna of this bed. Previously, only four species were known from here; Mr Laws has now brought the total up to 14, many of the

species being known only from here and the Target Gully shell-bed, while a few others occur elsewhere in the Awamoan, but not so far at Target Gully. A tabular comparison of the Volutes of these two shell-beds is interesting as showing the very close similarity between them and the remarkable number of species at this horizon (mostly limited to it). The present grand total of 21 species is far greater than in any other single zone in New Zealand, and runs very close to the number known from the Balcombian of Muddy Creek and Balcombe Bay in Australia (about 23). Another zone of the Awamoan (the united localities of Awamoa, Pukeuri, Rifle Butts, and Mount Harris) yields 19 species, while the Clifden beds (several zones) are probably third with a total of 14.

In the following table the relative abundance of the species is shown by giving the actual number of specimens collected by Mr Laws and myself, while an asterisk against a number indicates that the type is from that locality.

Species.	Target G.	Ardgowan.	Other Occurrences.
1. *Teremelon cognata* (Finlay)	*6		Pareora (J. M.).
2. *Pachymelon amoriaformis* Marwick	*1	1	Mount Harris.
3. *Pachymelon firma* Marwick	*2		
4. ,, *murdochi* Marwick	1		*Awamoa, Pukeuri.
5. *Metamelon reverta* (Finlay)	*2	8	
6. ,, *patruelis* Laws ..		*4	
7. ,, *informis* Laws ..		*1	
8. ,, *prominima* Laws		*3	
9. *Spinomelon parki* (Suter) ..		4	*Pareora, Mount Harris. Callaghan's Hill (J. M.).
10. ,, *benitens* (Finlay)	1	1	*Otiake.
11. ,, *aff. henryi* Laws		1	
12. *Alcithoe cylindrica* Marwick	*2	1	
13. ,, cf. *wekaensis* Marwick		2	
14. *Alcithoe familiaris* Marwick		1	*Mount Harris.
15. ,, *compressa* Marwick	*4		
16. ,, *armigera* Marwick		*1	
17. ,, *separabilis* Laws ..	3	*2	
18. ,, *lepida* Marwick ..	1	*12	
19. ,, *neglecta* Marwick ..	*1		
20. ,, *finlayi* Marwick ..	*12+ many juveniles.		
21. ,, *scopi* Marwick ..	*1		

The examination of this additional material enables me to clear up a few doubtful points and to correct one or two errors, as follows:

Genus *Metamelon*.—The numerous species of *Metamelon* in the Awamoan form a quite compact little group, springing no doubt from the smooth *inermis* from Otiake. The number of pillar plaits is variable, and there may be four or five in any species. Evidently narrow limits must be set for discrimination of species, the distinctive characters being the build of shell, shape of whorls, and especially the development of axials. In this way the Ardgowan shells fall easily into four species—*reverta* (Finlay); *patruelis* Laws, between

reverta and *inermis* in development of axials and shoulder; *informis* Laws, developed from *reverta* by reduction of axials; *prominima* Laws, foreshadowing *minima* Marwick, which seems to end the line. *M. minima* is apparently not a primitive form as Marwick thought, but a degenerate one, since it occurs only in later beds than *prominima*, which is halfway between it and *inermis* in shell features.

Genus *Spinomelon*.—The form, sculpture, and apex of the species Laws has described as *Spinomelon henryi* and *S. otaioensis* indicate close relationship with a Wharekuri n. sp., an Ardgowan shell, and my *Alcithoe residua* from Otiake. The last-named species was left "incertae sedis" by Marwick, but was referred by me definitely to *Spinomelon* as a somewhat aberrant line (*Trans. N.Z. Inst.*, vol. 61, p. 253; 1930) and a corresponding exception was noted to the normal apex of the genus. There are several lines in *Alcithoe*, and this group of species shows strong resemblance to some of them, but the protoconch of *otaioensis* is definitely that of *Spinomelon*, and seems to justify my reference to that genus. *Residua, otaioensis henryi*, and *whakinoensis* may be regarded as the nucleus of a line of *Spinomelon* from which sprang, in part at least, *Alcithoe*.

Spinomelon benitens (Finlay).—There is confusion in regard to this species. A large and beautiful shell which I obtained at Target Gully was recorded by Marwick as *parki* (*Trans. N.Z. Inst.*, vol. 56, p. 284; 1926), but differed considerably from all Mount Harris specimens in its smoothness, having the axials absent on the last 1½ whorls and elsewhere more distant and knob-like, with the shoulder weaker. Apart from its solid shell it agreed with the type of *benitens* from Otiake. Mr Laws has now collected at Ardgowan not only true *parki* (which I have not seen from Target Gully), but also a specimen similar to my Target Gully shell, which corresponds very closely with the type of *benitens*. The species, then, has a range from Waitakian to lowest Awamoan, and is closely allied to but much smoother than *parki*, which is not so variable as Marwick thought. An error I have myself made was the union of *Pachymelon waitakiensis* Marwick with *benitens* (*Trans. N.Z. Inst.*, vol. 61, p. 252; 1930). My topotype certainly has a remarkable resemblance both to Marwick's figure and to the type of *benitens*, but has the apical whorls missing; better specimens collected at Wharekuri by Mr Laws demonstrate that *waitakiensis* is apparently a very large *Teremelon* ancestral to *tumidior* Finlay; the exceptional size obscured this relationship before. Another error to which I must confess was the statement made at the same time that *Alcithoe turrita* Suter from Blue Cliffs is a *Spinomelon*. Mr Laws has since collected many specimens of Volutes from that locality, and his collection shows that the *Spinomelon* common there, while distinct from *parki* as I held, is not the real *turrita*, which was correctly placed by Marwick in *Alcithoe* s. l.

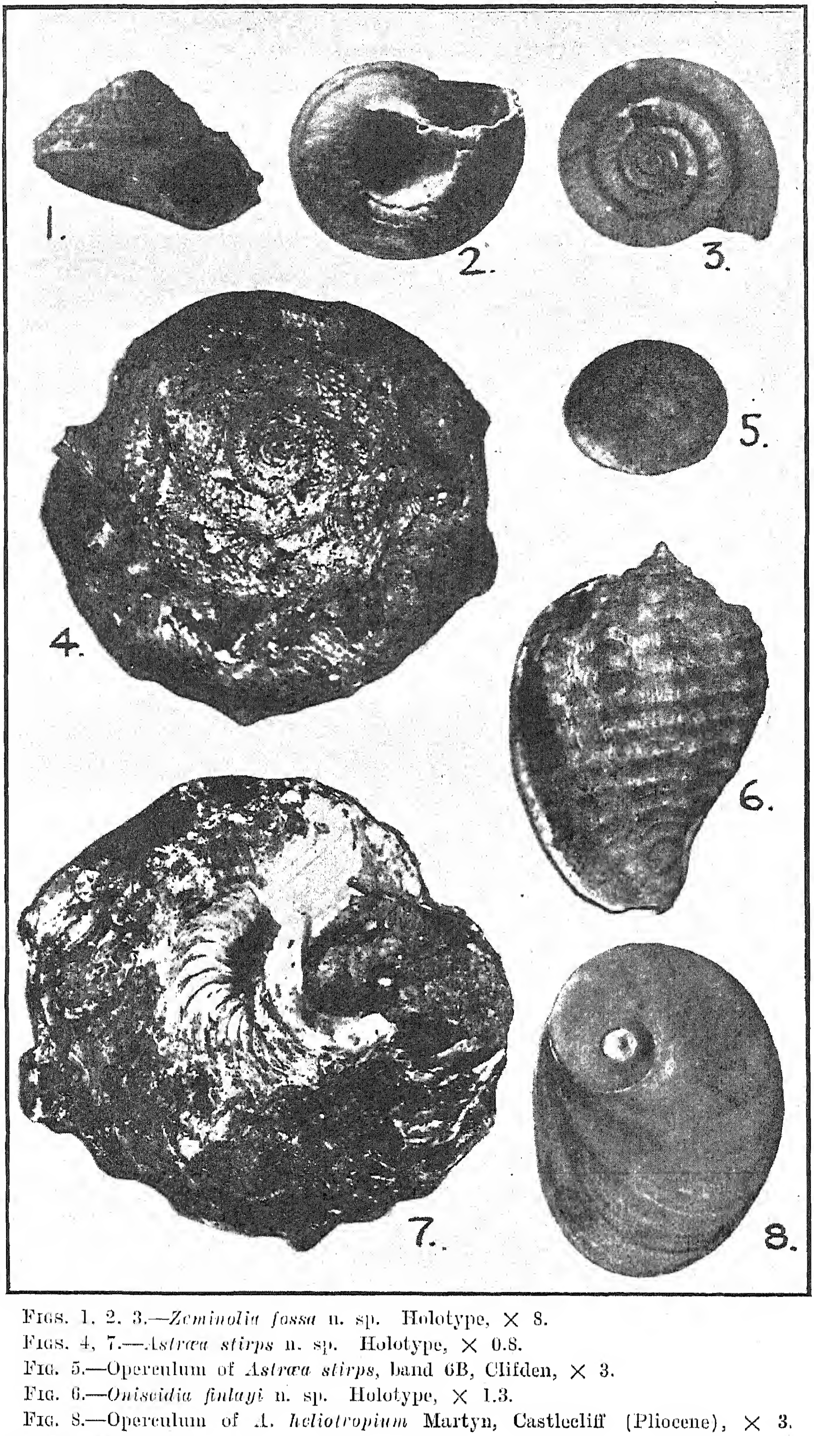
Alcithoe wekaensis Marwick.—The two Ardgowan specimens are very close, undoubtedly the same type of shell, but the nodules on the body-whorl are further apart and are fewer. Since only one specimen of *wekaensis* is known, and the Ardgowan shells are not too well preserved, it is likely that the differences are not specific. This

species at first sight closely simulates such high-spired forms as *detrita* Marwick, but the very swollen pillar with numerous plaits set on the swelling, instead of only 4 (and a weak fifth) hardly disturbing the normal course of the columella, indicate much more certain affinity with such species as *cylindrica* Marwick, in spite of the difference in shape.

Alcithoe familiaris Marwick.—Marwick compared this species (known then only from the unique type, with the lower part of the body-whorl missing) with the Recent *arabica*, but commented on the different pillar plaits. The Ardgowan specimen collected by Mr Laws agrees exactly with the type, but is more complete, and shows that this species is not of the *arabica* style with long body-whorl and aperture, but is relatively short for so large a species. It also shows quite clearly that it is a direct ancestor of *A. lutea* Marwick (and probably *A. transformis*), having an identical build, columella, and development of sculpture, but much stronger spines on last whorl. The four rather low pillar plaits (with a weak fifth) are quite different in style from those of the *wekaensis-cylindrica* line.

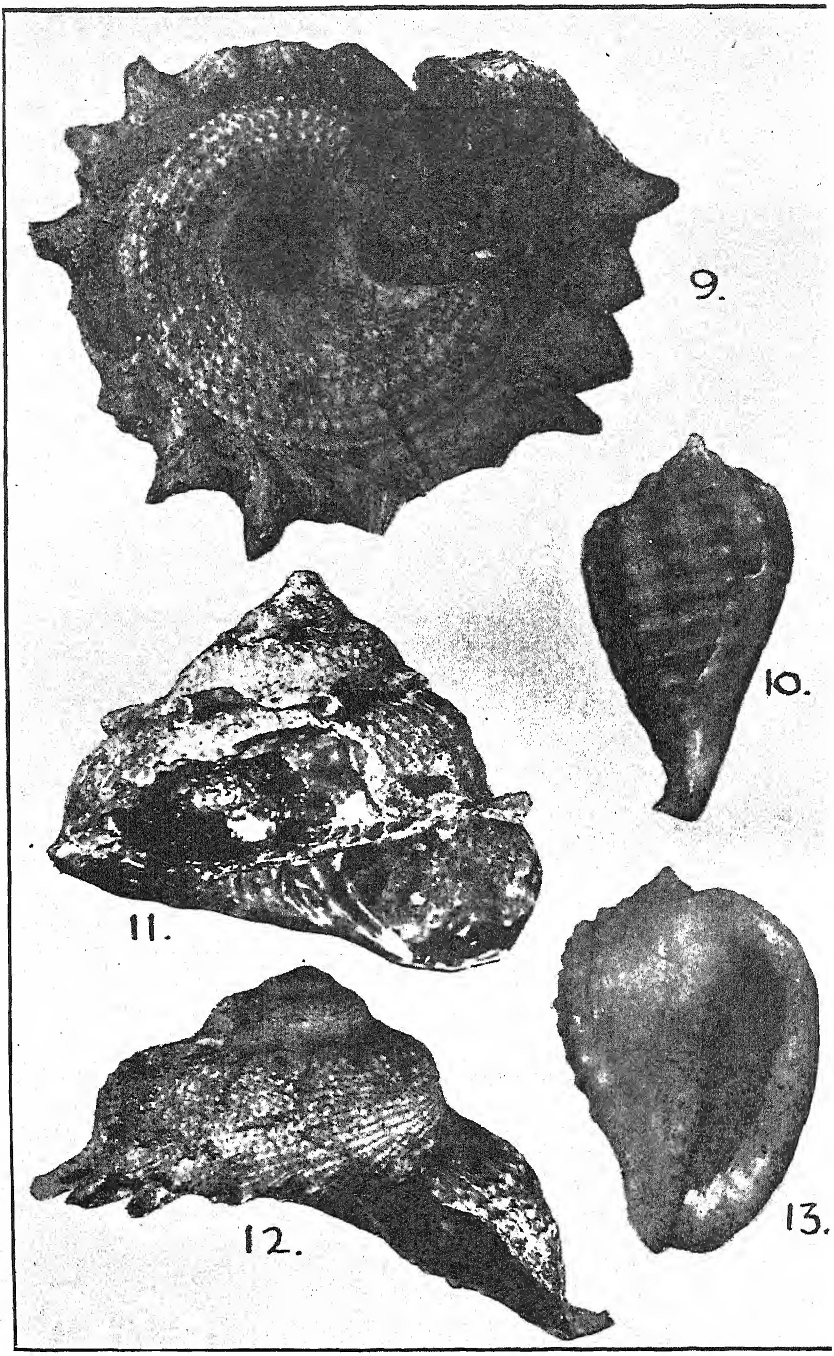
Alcithoe neglecta Marwick.—This is a good species. There is one other specimen from Target Gully (in my collection) besides the type, but no others are yet known; it is close to *lepida*, but shorter. *Lepida* is not uncommon at Ardgowan, but rare at Target Gully; I have one fragment and there are two in the Geological Survey collection, which Marwick took for juveniles of *cylindrica*. Juveniles of the large species are exceedingly uncommon at almost any locality; they apparently live in a different station. *A. finlayi* Marwick is an exception to this; juveniles are plentiful at Target Gully.

Alcithoe scopi Marwick. This is also a good species. The type is unique, but I have a closely related n. sp. from the Rifle Butts, showing the same type of apex, shell, and sculpture. The species of this group (*lepida, neglecta, reflexa, scopi*, and *separabilis*) need very careful examination and comparison for discrimination; one or two more still need description.

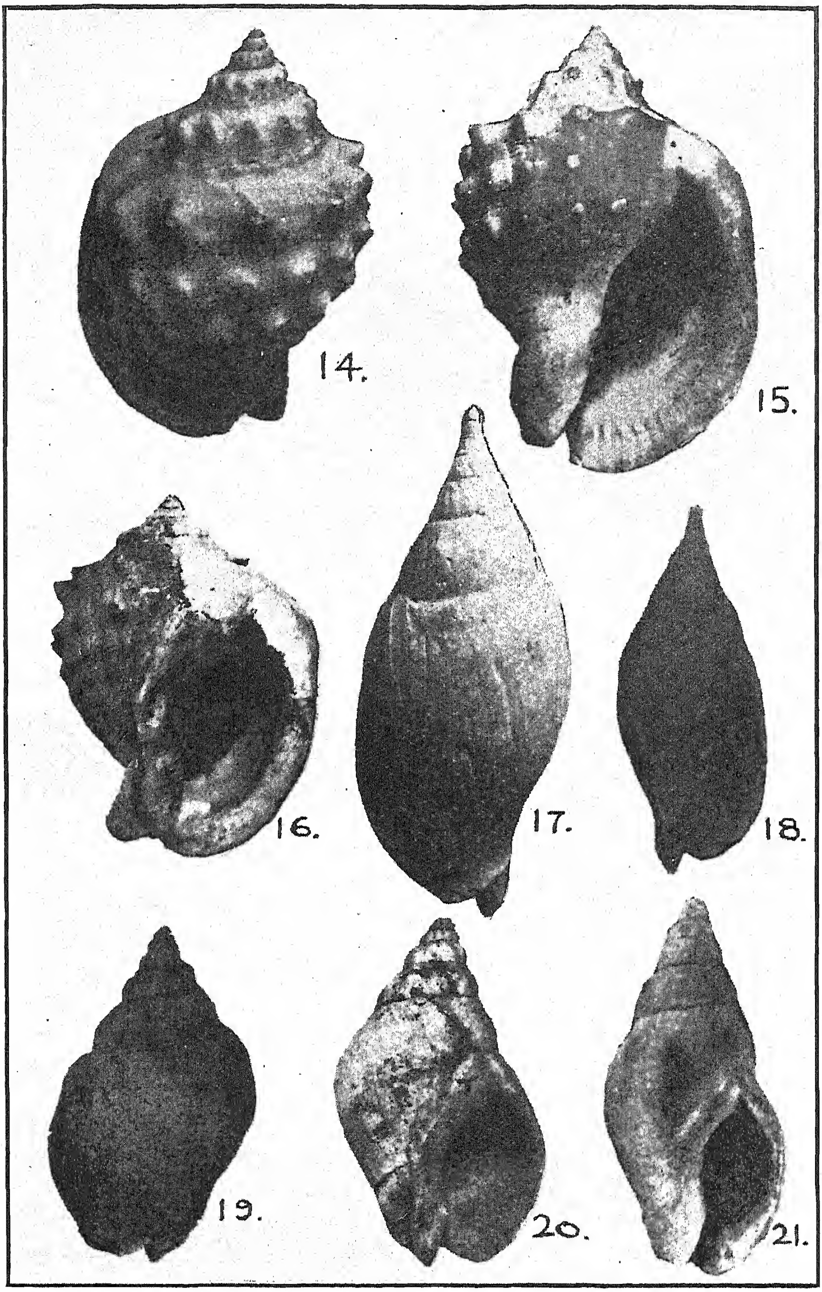


FIGS. 1, 2, 3.—*Zeminolia fossa* n. sp. Holotype, × 8.
FIGS. 4, 7.—*Astræa stirps* n. sp. Holotype, × 0.8.
FIG. 5.—Operculum of *Astræa stirps*, band 6B, Clifden, × 3.
FIG. 6.—*Oniscidia finlayi* n. sp. Holotype, × 1.3.
FIG. 8.—Operculum of *A. heliotropium* Martyn, Castlecliff (Pliocene), × 3.

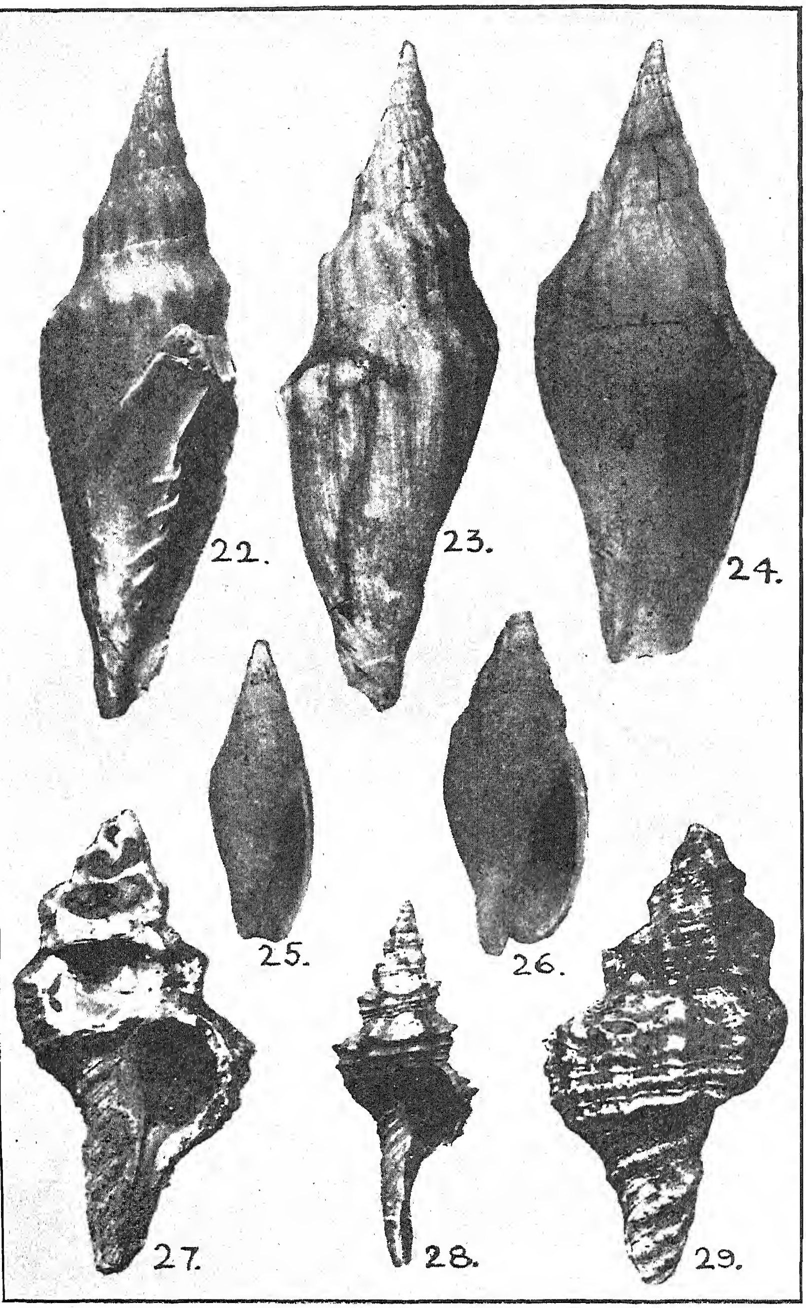
Face p. 202.]



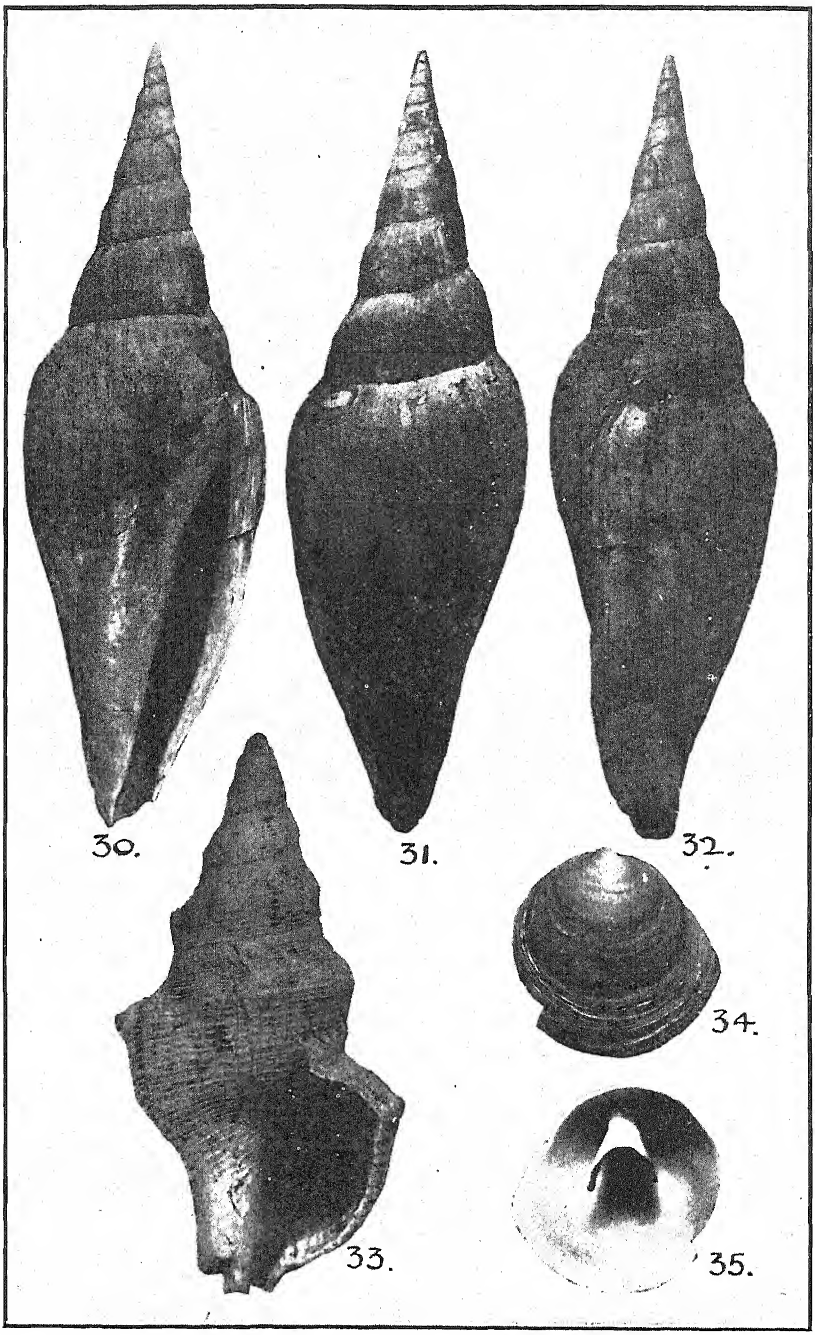
Figs. 9, 12.—*Astræa heliotropium* Martyn, Castlecliff (Pliocene). × 1.
Figs. 10, 13.—*Oniscidia finlayi* n. sp. Holotype, × 1.3.
Fig. 11.—*Astræa stirps* n. sp. Holotype, × 0.8.



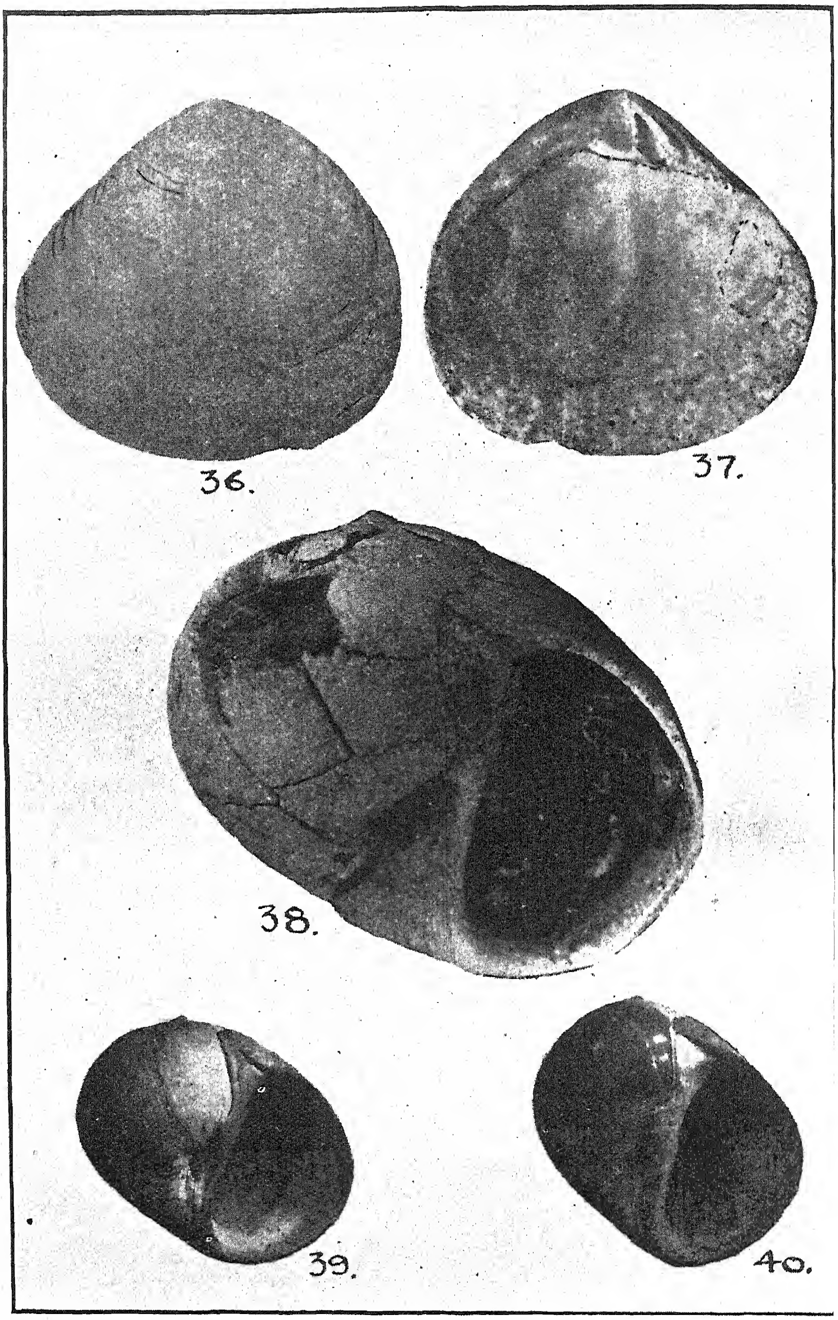
Figs. 14, 15.—*Euspinacassis emilyae* n. sp. Holotype, Fig. 15 × 1.1.
Fig. 16.—*Euspinacassis muricata* (Hector), Pakaurangi Point, × 1.1.
Figs. 17, 18.—*Metamelon patruelis* n. sp. Holotype, Fig. 18 × 1.1.
Fig. 20.—*Cominella (Acominia) kereruensis* n. sp. Holotype, × 0.8.
Fig. 19.—*Cominella (Acominia) kereruensis* n. sp. Paratype, × 0.9.
Fig. 21.—*Eucominia marshalli* n. sp. Holotype, × 3.



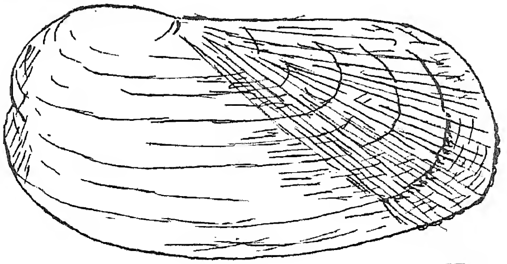
Figs. 22, 23.—*Spinomelon henryi* n. sp. Holotype, × 0.9.
Fig. 24.—*Alcithoe separabilis* n. sp. Holotype, × 1.1.
Fig. 25.—*Metamelon prominima* n. sp. Holotype, × 1.
Fig. 26.—*Metamelon informis* n. sp. Holotype, × 1.
Figs. 27, 29.—*Falsicolus inurbanus* n. sp. Holotype, × 1.3.
Fig. 28.—*Falsicolus corrugatus* (Marshall). Lectotype, × 2.8.



Figs. 30, 31, 32.—*Clifdenia turneri* n. gen. n. sp. Holotype, × 0.7.
Fig. 33.—*Falsicolus semilevigatus* n. sp. Holotype, × 1.2.
Figs. 34, 35.—*Cheilea plumea* n. sp. Holotype, × 2.5.



Figs. 36, 37.—*Talabrica nummaria* Powell. Topotype, × 2.9.
Fig. 38.—*Magnatica powelli* n. sp. Paratype, × 1.3.
Fig. 39.—*Magnatica powelli* n. sp. Holotype. × 0.8.
Fig. 40.—*Magnatica planispira* (Suter), Wharekuri greensand. × 0.8.



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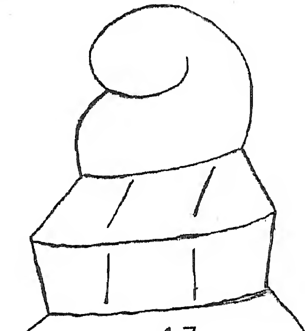

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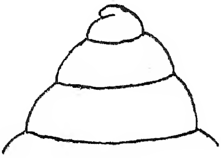

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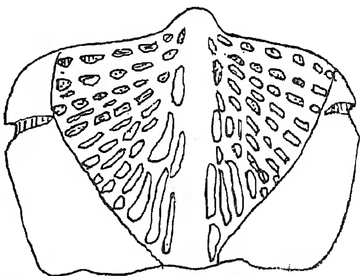

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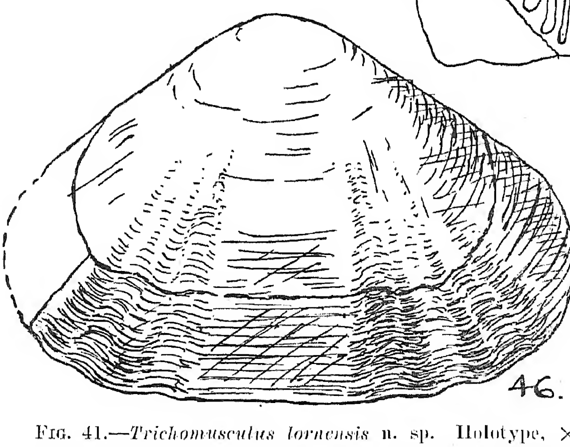

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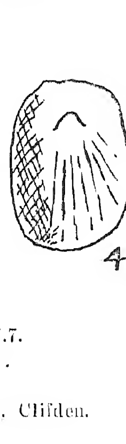

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Fig. 41.—*Trichomusculus lornensis* n. sp. Holotype, × 7.7.
Fig. 42.—Protoconch of *Falsicolus corrugatus* (Marshall).
Fig. 43.—Protoconch of *Fusus dictyotis* Tate.
Fig. 44.—Protoconch of *Oniscidia finlayi* n. sp., band 6B, Clifden.
Fig. 45.—*Loboplax ashbyi* n. sp. Holotype, × 9.
Fig. 46.—*Semeloidea miocenica* n. sp. Holotype, × 9.
Fig. 47.—*Notoacmea (Parvacmea) chattonensis* n. sp. Holotype, × 17.

The Recent Marginellidæ of New Zealand, with Descriptions of Some New Species.

By A. W. B. POWELL, Auckland Museum.

[*Read before the Auckland Institute, 19th August, 1930; received by Editor, 20th August, 1930; issued separately, 31st March, 1932.*]

IN this paper, six new species are described; two of them, however, were previously known from New Zealand, having been erroneously recorded under Australian specific names. Another record of an Australian species has been dismissed altogether, so the net gains to the fauna are really three, which brings the total of species to nineteen. Instead of the five species previously considered common to Australia and New Zealand, the present writer reduces this number to but one species, *mustelina* Angas.

The generic and subgeneric grouping has been revised as far as possible, but can only be considered provisional; for many of the genotypes are poorly figured, and specimens are not available in our local collections. Of the three genera employed, *Closia* is questionable, and of the three subgenera the same applies to both *Glabella* and *Serrata*.

Tomlin (1917, p. 246), in his Systematic List of the Marginellidae, has noted that " one very curious fact about this family . . . is the comparatively large number of cases of sinistrorsity which it supplies." " This teratological feature is so excessively rare amongst Recent marine gasteropods that I know of only thirty-seven or thirty-eight species in which it is on record, and of these, 50 per cent. are Marginellids."

To this list the present writer now adds the record of a sinistral Tasmanian " *aff. pygmaea* " from Swansea, specimen in writer's collection.

Genus *Marginella* Lamarck, 1799.

Type (by monotypy) *Voluta glabella* Linn. Recent, West Africa.

Subgenus *Glabella* Swainson, 1840, Treat. Malac., p. 324.

Type (by subsequent designation, Gray, 1847) *Voluta faba* Linn. Recent, West Africa; *Faba* Fischer, 1883, Type (by monotypy) *Voluta faba* Linn.

Omit from the synonymy of the above subgenus the following three genera referred there by Suter (1913, p. 461): " *Prunum* H. and A. Adams, 1853," which name should date from Hermannsen, 1852; *Egouena* Jousseaume, 1875; which together with *Prunum* differ

from *Glabella* in having the aperture channelled above and below, but without a basal sinus, and *Porcellana* Conrad, 1862, which is based on a shell congeneric with the type of *Volvarina.*

The type of Glabella is a moderately large shell with the basal canal distinctly notched, and is comparable in a broad sense with Australian species such as *formicula* and *muscaria* and the New Zealand *pygmaea*, except that in typical *Glabella* there is a definite colour pattern and a denticulate outer lip, features not present in the Australasian species ascribed to the subgenus.

The presence or absence of labial denticulations in the *Marginellidae*, however, does not seem to be of systematic importance as noted elsewhere in this paper under the subgenus *Volvarina.* It is noteworthy that *cleryi* Petit, one of the West African species, has all the characteristics of the genotype except that the outer lip is smooth within.

It is very doubtful if any of the Australasian species ascribed to *Glabella* are really typical, but until more is known about the dentition of existing genotypes it is unwise to create new genera. Tomlin (1917, p. 245) has stated that the radula of *Marginella* is an extremely difficult one to extract. For the benefit of any future worker investigating the radula of *faba* or allied West African species, I provide a figure of the radula of the New Zealand *pygmaea*, which species would make a suitable genotype for the Australasian series should they prove separable.*

Meanwhile *Glabella* may be retained for many of the Australian and New Zealand shells previously ascribed to that subgenus.

In the New Zealand Tertiary, however, the only true member of the Australasian group referable to *Glabella* so far described, is *M. hesterna* Bartrum and Powell, from Kaawa Creek (Waitotaran), Lower Pliocene. The remaining New Zealand Tertiary Marginellids all differ in having a weakly channelled basal canal without a sinus. *Glabella* (s. l.) then, so far as is known, was not represented in our fauna prior to the Pliocene.

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*With regard to Maltzan's *Pseudomarginella* (1880, Nachr. Mal. Ges., pp. 106-109) based on the alleged presence of an operculum in certain West African Marginellids, and the remarkable radulae claimed for this genus by Carrière (1880, Zool. Anz. 3, pp. 637-641), see paper by the Rev. Dr A. H. Cooke, "On the Pseudo-Genus *Pseudomarginella*" (Proc. Malac. Soc. Lond., vol. 15, pt. I, pp. 3-5, 1922). Dr Cooke discredits both Maltzan's and Carrière's results and advances very good reasons for doing so. He explains that an unfortunate mistake has evidently been made and repeats the obvious suggestion, considered even by Carrière, that the negroes who collected the shells for v. Maltzan extracted the soft parts of other mollusca and inserted them in the empty shells of *M. glabella.* Knowledge of the dentition in the genotypes of both *Marginella* and *Glabella* is necessary before the grouping of the Australasian series can be definitely settled.

Marginella (Glabella) pygmaea Sowerby. (Fig. 18).

1846. *Marginella pygmaea* Sowerby, Thes. Conch., I, p. 386, pl. 75, figs. 78 and 79.

1883. *Marginella pygmaea* Sowerby, Man. Conch. (I), vol. 5, p. 26, pl. 8, fig. 35 (= Thes. fig. 79).

1913. *Marginella (Glabella) pygmaea* (Sowerby) Suter, Man. N.Z. Mollusca, p. 465.

The type was " described without locality from a single specimen in the Bell collection " (Tryon, 1883, p. 26). Tomlin's (1917) entry for this species reads as follows: " Loc. —? (Coll. Bell). Type Brit. Mus., being the larger of two on one tablet; the smaller is labelled ' Brisbane, M. C.' " From the foregoing it is evident that the Brisbane specimen has no bearing on the type locality of *pygmaea,* and it is worthy of note that this species does not appear in Hedley's Queensland (1910) or his New South Wales (1918) check lists respectively, and that the common Tasmanian shells so determined by Tate and May are easily separable from New Zealand specimens.

The characteristic features of New Zealand shells are the high labial varix and the widely spaced plaits, the uppermost being at about half the height of the body-whorl. These essentials are shown in Tryon's copy of Sowerby's original figure. Tasmanian shells ascribed to *pygmaea* differ from the here assumed typical New Zealand species in having stronger and more closely spaced plaits, the uppermost situated proportionately lower in relation to the height of the body-whorl. The spire also is less blunt, and the labial varix not so high. Although my specimens prove conclusively that Tasmanian and New Zealand shells represent different species, I refrain from naming the Tasmanian form, as I have been unable to refer to the original figure and description of *pygmaea,* my remarks being based on Tryon's copy of Sowerby's original figure. In order to facilitate comparison with the type, I here figure both the New Zealand and Tasmanian species respectively, and provisionally nominate New Zealand as the typical locality for *pygmaea.*

Dimensions of typical *pygmaea*—

Height,	6·0 mm.;	diameter,	4·0 mm.	(Cape Maria van Diemen).
,,	7·1 mm.;	,,	4·8 mm.	(Mangonui Heads).
,,	7·0 mm.;	,,	4·3 mm.	(Whangaroa).

Dimensions of Tasmanian aff. *pygmaea*—

Height,	8·3 mm.;	diameter,	4·9 mm.	Swansea, Tasmania.
,,	8·0 mm.;	,,	4·7 mm.	
,,	7·7 mm.;	,,	4·5 mm.	

Habitat.—Cape Maria van Diemen (Rev. W. H. Webster coll.), Whangaroa; Rangaunu Bay, in 12 fath.; Tryphena Bay, in 5-6 fath., Great Barrier Is. (W. La Roche); Mokohinau Is. (H. Hamilton coll.); Takapuna Reef, Auckland (A. W. B. P.); Foveaux Strait, oyster dredge (A. Hamilton coll.); Chatham Is. (A. Hamilton coll.).

Dentition (Fig. 20). Radula extremely small. The solitary rachidian teeth are 0·057 mm. in width, have a deep sinus in the

basal plate, and are remarkable in having the central cusp extremely long and narrow. There are six much smaller cusps on either side of the central one.

So few species of the *Marginellidae* have had their dentition made known that the writer is unable to institute comparisons between the radula of *pygmaea* and that of other species. It may be noted, however, that the radula of Thiele's *M. ovata** and *aequatorialis* respectively, both from East Africa in deep water, have been figured by him (1925, pl. 198, text figs. 8 and 9 and pl. 22, figs. 11 and 12), and that these differ as much from each other as they do from that of the New Zealand *pygmaea,* although on shell characters *aequatorialis* is not greatly dissimilar from the New Zealand species.

Marginella (Glabella) vailei n. sp. (Figs. 15 and 23).

1904. *Marginella turbinata* Suter, in Hutton, Index Faunae Novae Zealandiae, p. 74 (not of Sowerby, 1846).

1913. *Marginella turbinata* Suter, Manual N.Z. Mollusca, p. 466 (not of Sowerby, 1846).

This species differs from true *turbinata* in having a less cylindrical shell with a taller and much more narrowly conical spire; in fact, the shape and general proportions are more like those of *pygmaea.* The relationship, however, is undoubtedly with *turbinata,* as shown by the presence of axials on the shoulder and a lightly defined fasciole, the upper limit of which is traceable as an inconspicuous line of junction proceeding from the uppermost plait. Above this in the New Zealand species is a moderately strong tubercle giving the appearance of a fifth plait. This is well developed in the three Spirits' Bay specimens, but is not shown in any of a long series of Tasmanian and New South Wales *turbinata* examined. Other characteristic features of *vailei* are the simple, broadly arcuate outer lip, not so heavily variced as in *turbinata* or *pygmaea,* leaving a proportionately more capacious aperture, and the slight concavity above the shoulder, the result of the more narrowly conic spire.

Shell attaining a larger size than *pygmaea,* solid, white. Whorls 4, including broadly rounded protoconch, surface worn, but presumably of about one whorl. Sculpture consisting of poorly developed axial fold-like riblets confined to the shoulder of body-whorl and more prominent over the latter part. These riblets are not even in spacing or development, and are much less prominent than in typical *turbinata.* In Suter's illustration (1915, pl. 20, fig. 20) these axials are an exaggeration even for true *turbinata,* which species nevertheless seems to have been the basis of Suter's illustration, for it lacks the characteristic spire of *vailei.*

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*This combination has been used three times previously, by Lea 1833, Emmons 1858, and Harris 1897, respectively. Another of Thiele's species, *Marginella aurora* (1925, p. 197), is invalidated by Dall's prior use of this combination in 1890. The writer wishes to call Professor Thiele's attention to this matter so that he may protect his specific rights by renaming these species at an early date.

Dimensions of *vailei*—

Height 8·10 mm.; diameter, 5 mm.:
Ratio of spire height into total height, 4·63.

Height 7·50 mm.; diameter, 4·6 mm.:
Ratio of spire height into total height, 5·00.

Height, —; diameter, 5·5 mm. (broken specimen).

Dimensions of *turbinata* (Shell Harbour, N.S.W.)—

Height, 8·25 mm.; diameter 4·9 mm:
Ratio of spire height into total height, 6·60.

Height, 8·50 mm.; diameter, 5·0 mm.:
Ratio of spire height into total height, 6·80.

Height, 10·00 mm.; diameter, 5·5 mm.:
Ratio of spire height into total height, 6·66.

Holotype, together with other molluscan material, presented to the Auckland Museum by Mr H. E. Vaile, September, 1930.

Habitat.—Cape Maria van Diemen (collected by Mr H. E. Vaile, 1896); Spirits' Bay (Charles Cooper collection).

Marginella (Glabella) muscaria Lamarck, 1822.

1880. *Erato lactea* Hutton, Man. N.Z. Mollusca, p. 63.
1884. *Marginella muscaria* Lamk., Trans. N.Z. Inst., vol. 16, p. 224.
1913. *Marginella muscaria* (Lamk.) Suter, Man. N.Z. Mollusca, p. 463.

Up to the present this species has been retained in New Zealand molluscan literature, but claims for its recognition are based on such slender evidence that I am forced to suspend it from our faunal list. Hutton's *Erato lactea,* 1880 was described without definite locality, Auckland to Cook Strait being mentioned. Later, Hutton in 1884 cited the habitat as Auckland and Cook Strait, but this is no doubt an error in transcription.

Hutton's types of *Erato lactea,* consisting of four specimens from the Dr Sinclair collection, have been examined through the courtesy of Mr W. R. B. Oliver, and these prove to be the common Australian *muscaria.* No locality is given on Hutton's original label, nor is there any authentic New Zealand record of the species by any subsequent writer.

Cheeseman (1887, p. 163) listed *muscaria* from Auckland Harbour, but his record was based upon the common *pygmaea,* which name had not been used at that time in connection with the New Zealand fauna.

Marginella (Glabella) tryphenensis n. sp. (Figs. 13 and 14).

Shell small, ovate-cylindrical, semitransparent, solid. Spire very little raised, only about one-twentieth height of aperture. Whorls about 3, including protoconch of one small flattened smooth whorl. Body-whorl long, tapering gradually over base, but not constricted. Columella with four oblique, moderately strong plaits. Aperture very long and narrow, with parallel sides, deeply channelled above

and broadly notched below. Outer lips strengthened on the outside by a moderately heavy variciform callus extending above to penultimate whorl. Colour pure white where thickened, remainder of the shell creamy buff.

Height, 3·66 mm.; diameter, 2·2 mm.

Holotype presented to Auckland Museum.

Habitat.—Tryphena Bay, in 5-6 fath., Great Barrier Island (type) (dredged A. W. B. P., Jan., 1924).

Tryphenensis is probably related to Sowerby's *inconspicua*, described without locality, but since claimed as a constituent of the New South Wales and Tasmanian faunas respectively.

Marginella (Glabella) larochei n. sp. (Figs. 16 and 17).

Shell small, ovate-cylindrical, semitransparent, moderately solid. Spire narrowly conical, straight in outline, about one-quarter height of aperture. Whorls 4, including low flattened smooth protoconch of one small, bluntly rounded whorl. Suture indistinct, tangential, false margined, due to the transparency of the shell. Aperture high and narrow, rather deeply channelled above, narrower and shallowly notched below. Outer lip simple, smooth, not thickened within, but strengthened on the outside by a flattened variciform callus. Body-whorl moderately inflated, not constricted over base. Columella with four strong oblique plaits, the lower two more closely spaced and extending further over the fasciole. Fasciole ill-defined, line of junction at uppermost plait. There is a moderately heavy callus at about the middle of the fasciole, causing the slight swelling shown in the outline. Colour white where thickened, normally vitreous.

Height, 4·16 mm.; diameter, 2·26 mm.

Holotype in author's collection.

Habitat.—Rangaunu Bay, in 12 fath. (type) (W. La Roche, 1922); 23 fath., off Ahipara Bay (D. Crawford, 1925); off Wanganui in 10-12 fath. (W. La Roche).

Subgenus *Volvarina* Hinds, 1844.*

Type (by original designation) *Marginella avena* Valenciennes. Recent, West Indies.

So far as can be judged from shell characters, Australasian species such as *maoriana* nov., *hectori* Kirk, and *hedleyi* May, seem related to the genotype. This apparent relationship is not surprising for species ascribed to *Volvarina* are widely distributed geographically. The genotype is a white glossy shell of the same cylindrical, short-spired type as our Australasian shells; the outer lip is as in *maoriana*,

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*Grant and Gale, 1931, mem. San Diego Soc. Nat. Hist., vol. 1, p. 629, state that Martini's figure of *pellucida* Schumacher, the monotype of the genus *Hyalina* Schum. (1817), is recognisable as a species close to *californica* (Tomlin) and therefore *Hyalina* has priority over *Volvarina*. However, until the exact identity of the *pellucida*, which was declared indeterminable by Tomlin (1917, p. 288), can be definitely settled, it seems better to ignore *Hyalina*.

being without denticles along its inner edge, and the shell varies in height from about 8·5 mm. to 13 mm. *Mustelina* and two of the New Zealand Tertiary species here ascribed to this subgenus have weak denticulations along the inner side of the outer lip. The presence or absence of these denticles, however, is certainly not of greater than specific value.

Marginella (Volvarina) mustelina (Angas).

1871. *Hyalina (Volvarina) mustelina* Angas, Proc. Zool. Soc., p. 14, pl. 1, fig. 5.

1913. *Marginella (Volvarina) mustelina* (Angas) Suter, Manual N.Z. Mollusca, p. 460.

Type in British Museum. Dredged off Sow and Pigs Reef, Port Jackson (Brazier).

The colour pattern in New Zealand examples is more decided than in Shell Harbour (New South Wales) specimens, due to the pattern being darker and the ground colour more whitish. The Shell Harbour specimens have the same pattern, but a slightly different appearance results from less contrasting tones due to paler zones and a darker ground colour. No structural shell differences were noted, although a series of thirty Shell Harbour specimens were compared with a similar number from North Auckland localities.

Specimens from 10-30 metres of Sunday Island, Kermadec Islands, one of which is here figured (Fig. 22), closely resemble typical *mustelina,* except that there are no labial denticulations and the colour pattern is in the form of simple zones without darker markings. Possibly this form is identical with Ten.-Woods *stanislas,* which has been synonymised with *mustelina,* and is a form I have not seen.

Habitat (in New Zealand) Doubtless Bay, under stones at low tide (A. E. Brookes); Whangaroa Harbour (W. La Roche); Tryphena, Great Barrier Island, on under-sides of stones, firmly embedded in sand.

Dentition.—Nine "live" specimens were utilised, but a most careful search failed in the location of a radula.†

Marginella (Volvarina) maoriana n. sp. (Fig. 21).

Shell moderately large, cylindrical, no sculpture, smooth and polished, rather thin. Spire short, less than one-sixth height of aperture. Whorls very rapidly increasing, 4½, including low broadly rounded smooth protoconch of 1½ whorls. Body-whorl very long and narrow, cylindrical, sides very gradually contracting over base, but nowhere constricted. Aperture high and narrow, subchannelled above, rather broadly open below, but without a sinus. Outer lip vertical, almost straight, slightly thickened and incurved, with a smooth inner margin. Columella with four equidistant oblique plaits

†It is noteworthy that Nellie B. Eales, 1923 (British Antarctic "Terra Nova" Expd., Nat. Hist. Report, Mollusca, Pt. 5, p. 38) found radula and jaws absent from *Marginella hyalina* Thiele, a deep-water Antarctic species.

and a moderately strong denticle immediately above uppermost plait, giving the appearance of a weakly developed fifth plait. Colour whitish with three spiral bands of bright orange-brown, a narrow one at suture, another slightly wider just above denticle on columella, and a third conspicuously wider situated between the other two, and occupying the upper third of a broad zone of pale orange-brown. The lower third of this zone is slightly darker than in the middle. On the spire whorls only the sutural band is visible.

Height, 8·8 mm.; diameter, 3·8 mm. (holotype).
" 9·0 mm.; " 4·25 mm. (Leigh specimen).
" 9·0 mm.; " 4·25 mm. (Castlecliff specimen).

Holotype in author's collection.

Habitat.—Oruawharo, east coast Great Barrier Island, (type) empty shell from rock-pool (A. W. B. P., Jan., 1924); Leigh, Hauraki Gulf (Mr Goffe); Castlecliff, Wanganui (Castlecliffian), Upper Pliocene (A. W. B. P., Jan., 1927).

Compared with *mustelina, maoriana* is a thinner shell with a more elevated conic spire, the outer lip is only feebly thickened, lacking denticles on its inner edge, the colour pattern is distinctive and there is a denticle present on the columella above the plaits. This columellar denticle is present in the Castlecliff specimens, but not in the Recent *mustelina*, or *hectori* Kirk from the Pliocene of Petane, which latter species seems to be directly ancestral to *maoriana*. *Kirki* Marwick and *marwicki* Finlay are somewhat similar shells in which the inside of the outer lip is finely denticulate. A Recent Tasmanian species of the *maoriana* type is May's *M. hedleyi*.

Subgenus *Serrata* Jousseaume, 1875.

Type (by tautonomy) *Marginella serrata* Gaskoin, Recent, Mauritius.

The genotype is about 7·5 mm. in height, has a simple lower canal slightly channelled but not notched, and the inside of the outer lip is finely denticulated. *Serrata* has been preferred to *Eratoidea* of Weinkauff 1879, as Woodring (1928, p. 240) has noted that *Eratoidea* will probably prove a synonym of *Serrata*.

The New Zealand shells are grouped here provisionally, mainly on account of the weakly channelled basal canal without a sinus, combined with elongate basally tapered outline and a tendency towards denticulation of the inner edge of the outer lip.

Marginella (Serrata) subfusula n. sp. (Figs. 3 and 4).

Shell small, rather thin, ovate, basally tapered, smooth and polished. Spire less than one-third of aperture. Whorls 4, including protoconch of 1½ broadly rounded smooth whorls. Body-whorl long, broadly rounded above the middle and tapered below, but nowhere constricted. Columella with four moderately strong oblique plaits. Aperture very long, narrow, with parallel sides, channelled above and below, but without a basal sinus. Outer lip strengthened by a

long, straight, evenly developed variciform callus which dies out at the upper channel before reaching the body-whorl. Colour dull-white.

Height, 4·00 mm.; diameter, 2·26 mm. (holotype).

Holotype and two paratypes in the Charles Cooper collection, presented to the Auckland Museum, 1929.

Habitat.—Off the Poor Knights Islands in 70 fathoms; (type) off Poor Knights Islands in 60 fathoms (A. W. B. P. collection, ex. Captain J. Bollons).

This species is intermediate in character between *hebescens* and *fusula*. It has the broad spire-whorls of the former although proportionately shorter, but lacks the characteristic basal swelling. From *fusula* it differs in having a considerably shorter and more broadly rounded spire.

Marginella (Serrata) cairoma Brookes. (Fig. 6).

1924. *Marginella cairoma* Brookes, Trans. N.Z. Inst., vol. 55, p. 154., pl. 7, figs. 4 and 5.

1913. *Marginella allporti* Suter (in part, not of Ten. Woods, 1876, "Lyall Bay") Manual N.Z. Mollusca, p. 459.

Marginella allporti must be dismissed from the New Zealand fauna, as *cairoma* and *aoteana* (a new species described below) together replace all the New Zealand records of this Tasmanian species given in Suter's manual. Compared with *cairoma* and *aoteana*, the Tasmanian *allporti* is a more inflated shell, this being so particularly with regard to the spire-whorls. The aperture also differs greatly in being relatively wider and shorter, and finally the colour bands are very distinctive. *Allporti* has three bands on the body-whorl, a narrow one above, a second narrow one proceeding from the junction of the outer lip with body-whorl, and a third, a wider one, situated lower down. In *cairoma* and *aoteana* the colour bands are restricted to two narrow ones, the upper one proceeding from the junction of outer lip with body-whorl and the second one situated lower down.

In order to facilitate a comparison, the writer provides camera lucida tracings of a Tasmanian specimen of *allporti* (Fig. 7), together with a figure each of *cairoma* (Fig. 6) and its benthal relative *aoteana* (Fig. 5). With regard to one of Suter's records of "*allporti*," "Lyall Bay (A. Hamilton)," the writer has these specimens before him and they prove to be typical *cairoma*. During a recent visit to Wanganui, the writer found that the specimens upon which Suter's other records of *allporti* were based were separable from the Tasmanian species and identical with the species described below.

The localities for Suter's specimens were Cuvier Island, 38 fath.; Little Barrier Island, 20 fath.; and Channel Island, 25 fath.

The writer has examined series of *cairoma* from the following localities:—Russell, Bay of Islands (A. E. Brookes); Tryphena, Great Barrier Island (under sides of stones embedded in sand near low-water mark, A. W. B. P., Jan., 1923); Whangaroa (W. La Roche,

1924); Poor Knights Islands (Shore) (C. Cooper coll.); Motutapu Island, Hauraki Gulf (under sides of stones at low-water, A. W. B. P., Jan., 1921); Lyall Bay (ex A. Hamilton coll.).

The figured specimen of *cairoma* is from Whangaroa, and is in the writer's collection; the figured specimen of *allporti* is from Tasmania, and is from the Rev. W. H. Webster's collection, which was recently presented to the Auckland Museum.

Marginella (Serrata) aoteana n. sp. (Fig. 5).

1913. *Marginella (Eratoidea) allporti* Suter (in part, not of Ten. Woods, 1876), Manual N.Z. Mollusca, p. 459.

1928. *Marginella allporti* (?) Finlay (not of Ten. Woods, 1876), Trans. N.Z Inst., vol. 59, p. 249.

This species is a more heavily built shell than *cairoma* and is rather different in outline. The body-whorl has proportionately a slightly greater diameter, the periphery is more narrowly rounded and the outline more biconic, the result of more rapid tapering towards protoconch and base.

The protoconch is smaller than in *cairoma* and the outer lip is considerably stronger, being greatly thickened on the inner side and furnished with a moderately strong denticle situated at a higher level than the uppermost plait. Immediately below this denticle a rudimentary second denticle is sometimes present.

The colour pattern is indicated by one or two terminal blotches on outer lip corresponding to the colour bands in *cairoma*; the ground colour is whitish or pale creamy-buff. Whorls 4. This species is closely allied to *cairoma*, and both may be considered New Zealand relatives of the Tasmanian *allporti*. From *cairoma* it differs constantly in the characters mentioned above, and so far has not been found living in the littoral.

The writer has found *cairoma* at Tryphena, living on the under sides of stones embedded in sand, but only within a narrow zone near low-water, they being absent from all stones examined below this.

Some specimens of *cairoma* have a thickened pad just above the point of termination of the upper colour band on the inside of the outer lip, but this is never developed as a tubercle and the outline of the shells is constantly more cylindrical.

Dimensions of *aoteana*.—Height, 4·6 mm.; diameter, 2·2 mm. (holotype).

Dimensions of *cairoma*.—Height, 4·6 mm.; diameter, 2·1 mm. (Tryphena).

Holotype in author's collection.

Habitat.—Rangaunu Bay, in 12 fath. (type) (W. La Roche, 1922); Mangonui Heads, in 6-10 fath. (W. La Roche, 1922); Tryphena Bay, in 5-6 fath., Great Barrier Island (A. W. B. P., Jan., 1924); Chatham Islands (ex A. Hamilton coll.).

Hedley's *kemblensis* should be recognised as a distinct species and not included in the synonymy of *allporti* as placed by Suter.

Genus *Gibberula* Swainson, 1840, Treat. Malac., p. 323.

Type (by monotypy) "*G. zonata* En. Meth. 374, fig. 6" (= *oryza* Lamk.).

The reference of the New Zealand *ficula* to *Cryptospira* Hinds should be discontinued; the genotype being a large heavy shell up to 1½ inches in height, with five strong columellar plaits and a heavily callused labial varix having a smooth inner margin. On the other hand, the use of *Gibberula* for *ficula* seems reasonable. I have not seen specimens of the genotype, but it is described as being a small species with a length of about 8 mm., and according to Tryon (1883, p. 40), "has the spire apparent, although short. There are four columellar folds, and in addition a number of transverse denticulations extending nearly the entire length of the inner lip."

The New Zealand shell compares very well with actual specimens of the Mediterranean *miliaria,* the species cited as genotype of *Gibberula* by Suter (1913, p. 466). *Miliaria* has the characteristic transverse denticulations above the plaits, and like the New Zealand species has a series of similar denticulations along the inside of the outer lip.

Evidently *Gibberula* has a wide distribution, and there is no reason to doubt the reference of the New Zealand species to that genus.

Gibberula ficula (Murdoch and Suter, 1906).

Habitat.—Off Great Barrier Island, in 110 fath. (type); Rangaunu Bay, in 12 fath. (W. La Roche, 1922).

Genus *Closia* Gray, 1857.

Type (by monotypy) *Marginella sarda* Kiener, Recent, Indo-Pacific.

Closia profunda (Suter, 1909).

I have seen neither the genotype nor topotypic specimens of the New Zealand species, so Suter's classification is followed, except that the association with *Cryptospira* is severed as in the previous species.

SUMMARY OF THE RECENT MARGINELLIDAE OF NEW ZEALAND.

1. *Marginella (Glabella) pygmaea* Sowerby, 1846.
2. " " *vailei* Powell, 1932.
3. " " *trphenensis* Powell, 1932.
4. " " *larochei* Powell, 1932.

5. *Marginella (Volvarina) mustelina* (Angas, 1871).
6. ,, ,, *maoriana* Powell, 1932.
7. ,, ,, *albescens* Hutton, 1873.
8. ,, ,, *parvistriata* Suter, 1908.
9. ,, ,, *plicatula* Suter, 1910.
10. *Marginella (Serrata) cairoma* Brookes, 1924.
11. ,, ,, *aoteana* Powell, 1932.
12. ,, ,, *fusula* Murdoch and Suter, 1906.
13. ,, ,, *subfusula* Powell, 1932.
14. ,, ,, *hebescens* Murdoch and Suter, 1906.
15. ,, ,, *lurida* Suter, 1908.
16. ,, ,, *stewartiana* Suter, 1908.
17. ,, ,, *amoena* Suter, 1908.
18. *Gibberula ficula* Murdoch and Suter, 1906.
19. *Closia profunda* Suter, 1909.

"*Marginella*" *coma* Odhner, 1924, Cape Maria van Diemen, in 50 fath. A species of uncertain status and probably not a member of the *Marginellidae.*

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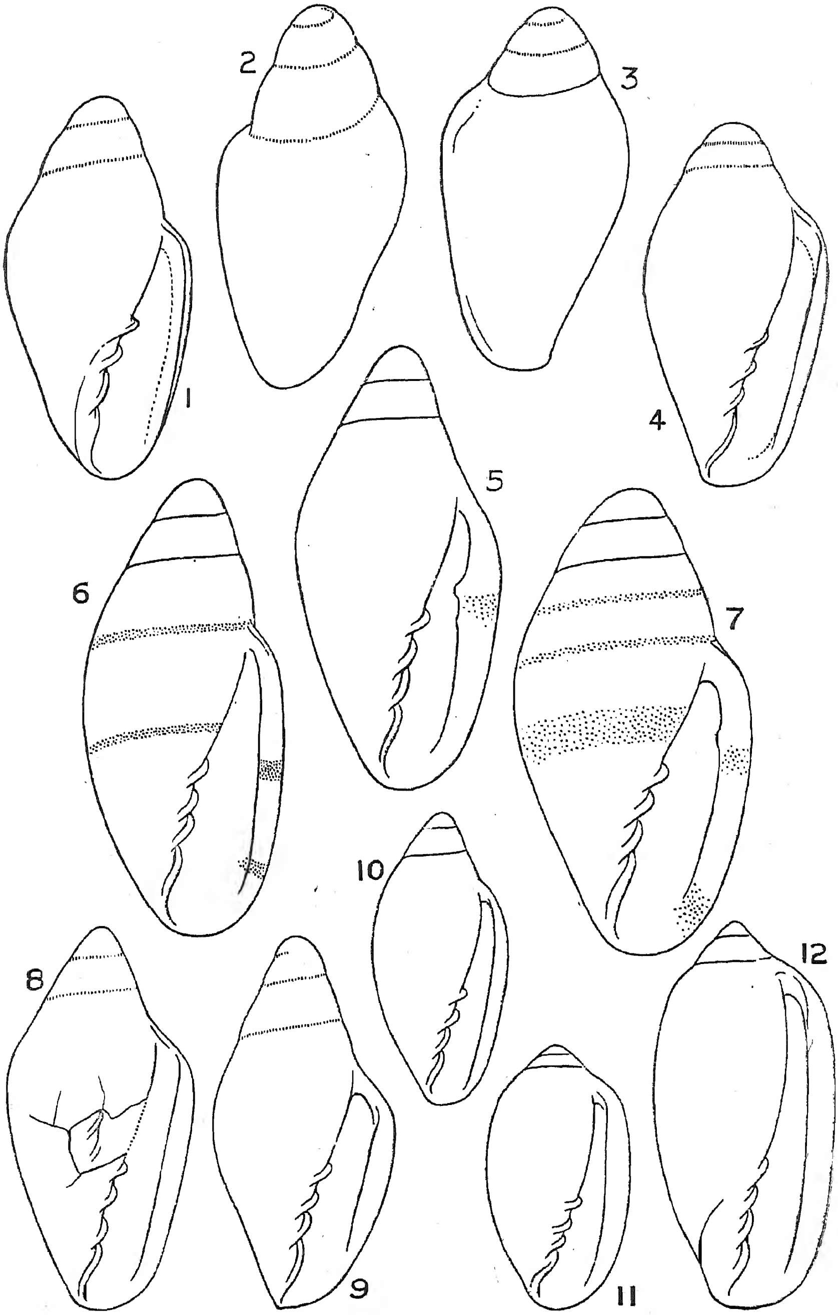
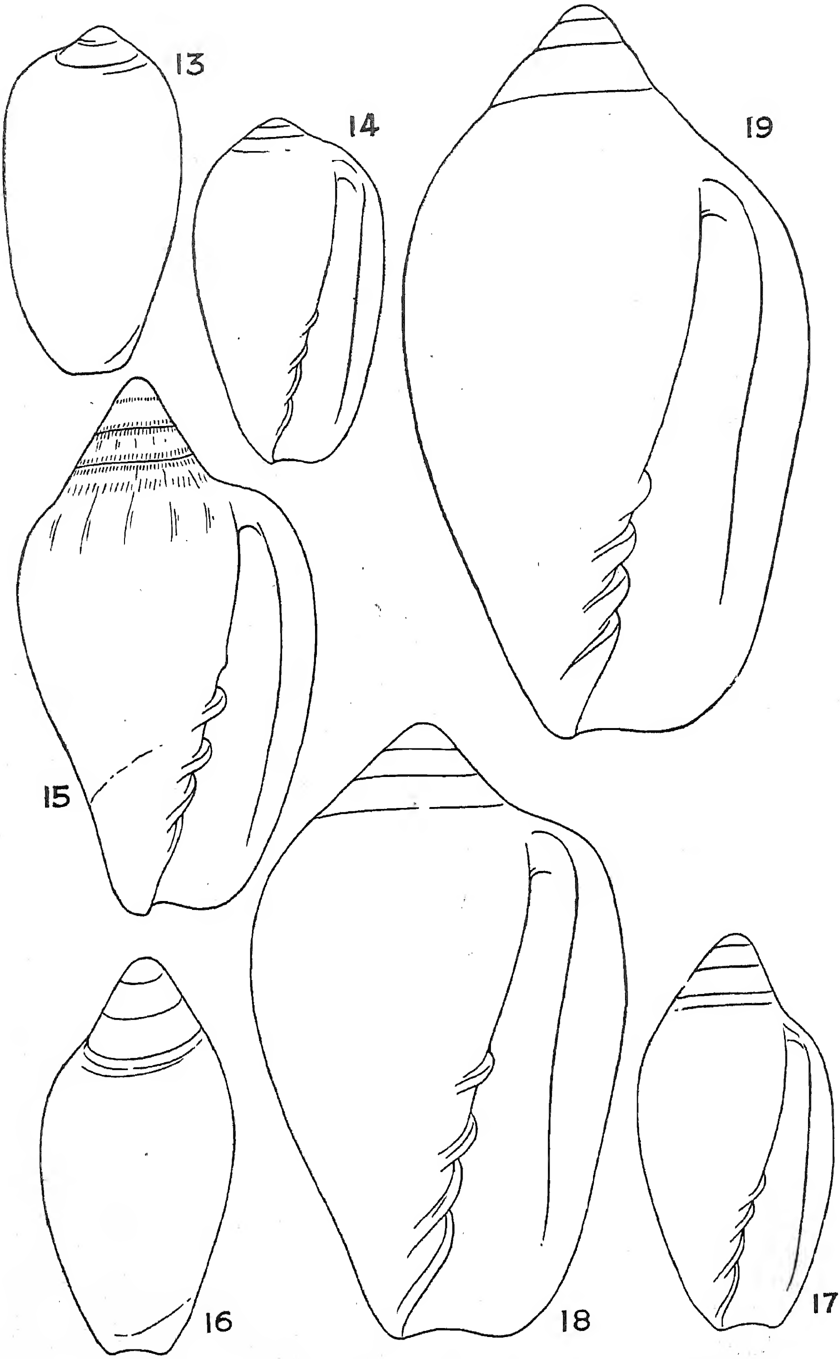


FIGS. 1 AND 2.—*Marginella (Serrata) hebescens* Murd. and Suter. Topotype.
FIGS. 3 AND 4.— „ „ *subfusula* n. sp. Holotype.
FIG. 5.—*Marginella (Serrata) aoteana* n. sp. Holotype.
FIG. 6.— „ „ *cairoma* Brookes (Whangaroa).
FIG. 7.— „ „ *allporti* Ten. Woods (Tasmania).
FIG. 8.— „ „ *stewartiana* Suter. Topotype.
FIG. 9.— „ „ *fusula* Murd. and Suter. Topotype.
FIG. 10.— „ „ *lurida* Suter. Topotype.
FIG. 11.—*Marginella (Volvarina) parvistriata* Suter. Topotype.
FIG. 12.— „ „ *albescens* Hutton. Topotype.



Figs. 13 and 14.—*Marginella (Glabella) tryphenensis* n. sp. Holotype.
Fig. 15.—*Marginella (Glabella) railei* n. sp. Holotype.
Figs. 16 and 17.—*Marginella (Glabella) larochei* n. sp. Holotype.
Fig. 18.—*Marginella (Glabella) pygmaea* Sowerby (Whangaroa).
Fig. 19.— „ „ aff. *pygmaea* (Swansea, Tasmania).

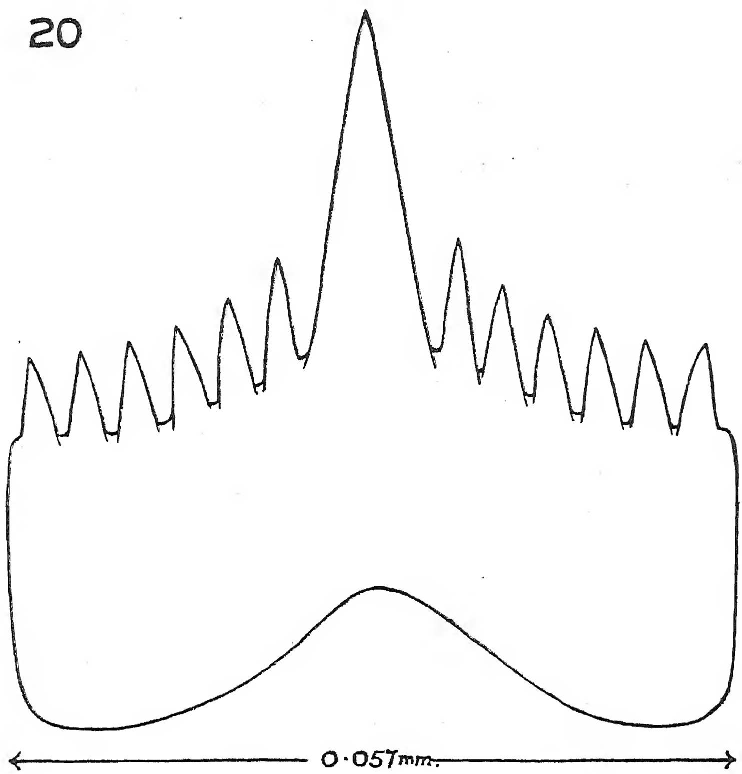


Fig. 20.—Rachidian tooth, radula of *M. pygmaea* Sowerby (Port Fitzroy, Great Barrier Island).

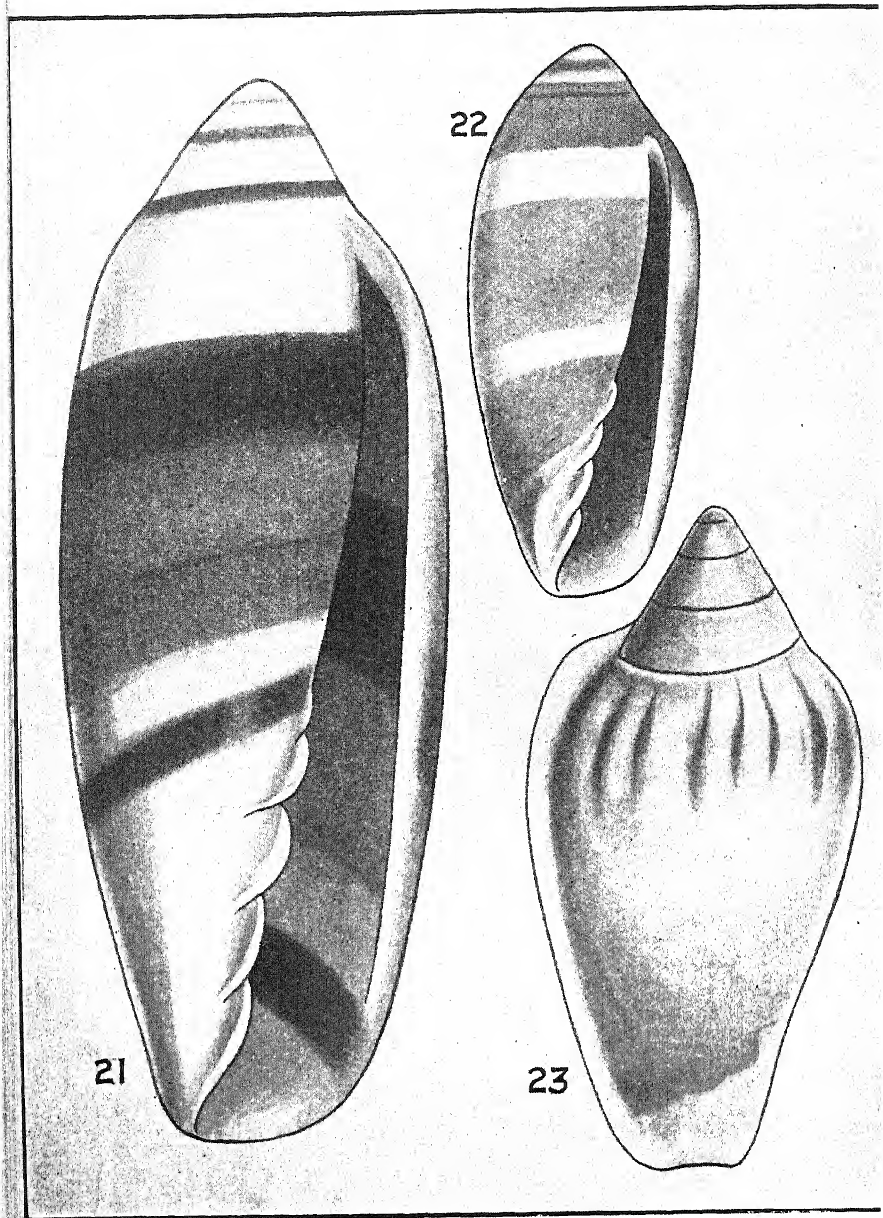


FIG. 21.—*Marginella (Volvarina) maoriana* n. sp. Holotype.
FIG. 22.— „ „ c.f. *mustelina* Angas (Kermadec Islands).
FIG. 23.—*Marginella (Glabella) railei* n. sp. Holotype.

Tinguaites and Camptonites from the Vicinity of Haast Pass.

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CONTENTS.

INTRODUCTION.

THE rocks described in this paper were collected early in 1930 from boulders in the beds of streams on either side of the Main Divide, in the vicinity of Haast Pass, on the boundary between North-west Otago and South Westland.

On the Otago side of the divide, the boulders in question occur in the bed of the Makarora River for some distance below its junction with the Fish, as well as in the latter stream itself. At the point where the Makarora joins the Fish, it emerges from a precipitous, impassable canyon, so that it was not possible to ascertain whether boulders of the same type are to be found in the Makarora, upstream from the confluence.

On the Westland side of the pass, igneous rocks are not represented among the boulders in the upper part of the Haast; but they were found to be plentiful in the bed of a small stream which enters the Haast from the west, about one mile below its junction with the Burke.

Thus, although these rocks were never actually observed *in situ*, it is safe to assume that their source lies in the wild and unexplored ranges that stretch northward from the headwaters of the Fish, across the Burke, towards the junction of the Haast and the Landsborough. The whole of this region is composed of a varied assemblage of mica-, chlorite-, and epidote-schists, which are continuous with the schists of Central Otago further south-east. The igneous rocks in question must therefore occur as dykes invading this schist formation.

PETROGRAPHY.

I.—Tinguaites:

Specimens Nos. 1293,* 1298, 1299, and 1300 were collected from the stream flowing into the Haast one mile below the mouth of the Burke. Nos. 1294, 1295, 1296, and 1297 were obtained from boulders in the Makarora River, two miles below the confluence with the Fish River.

1294, Cancrinite-tinguaite. In hand specimen, a green, even-grained rock without noticeable phenocrysts. In section it is seen to consist of feldspar 45%, cancrinite 25%, aegirine 15%, zeolite 10%, sodalite 5%, and accessory apatite. (These figures, and all similar percentages in this paper, are approximate estimates only and are not based on micrometric measurements). The feldspar is in subidiomorphic tabular crystals about 2 mm. in length, being considerably larger than crystals of the other minerals present. They are untwinned or simply twinned, with refractive index well below that of Canada balsam, and invariably show pronounced perthitic striping parallel to the direction of elongation. Slender acicular inclusions of aegirine are sometimes present. The optic sign is positive, and the extinction angle in sections perpendicular to the acute bisectrix Z is 14° (measured from X to the basal cleavage). The main mass of each crystal is therefore albite carrying up to perhaps 10% of the anorthite molecule, and the feldspar as a whole may be classed as an albite-rich perthite. Cancrinite is abundant in clear allotriomorphic or subidiomorphic crystals about 0·3 mm. in diameter. It is clearly of primary origin, and is unaltered, except in one or two instances where there is come change to muscovite. Nephelite is absent; but there are numerous sharply bounded hexagonal and rectangular aggregates of finely crystalline zeolitic material, which are almost certainly pseudomorphs after nephelite. They measure up to 1 mm. in length, and are scattered throughout the whole rock. The zeolite is in minute acicular prisms with a more or less radial arrangement in the hexagonal aggregates. The refractive index is considerably less than γ for cancrinite (1·515 to 1·524), but slightly greater than α (1·491 to 1·502). The elongation of the fibres is positive and the extinction is straight or possibly very slightly oblique. The birefringence is distinctly higher than that of the feldspar, and is probably about 0·012 to 0·015. The positive elongation and straight or only slightly inclined extinction exclude all the fibrous zeolites except natrolite, epistilbite, and the rare erionite (Winchell, 1927, p. 389). The last-named may be excluded on account of its low refractive index and its chemical composition. Epistilbite is also unlikely on account of its calcic composition, extinction angle of 10°, and slightly low birefringence. All the properties agree well with natrolite, except that the refractive index of natrolite is 1·473 to 1·493, while the mineral in question undoubtedly has a refractive index as high as 1·500. It is therefore identified

*Unless otherwise stated, all numbers refer to specimens and sections in the Otago University collection.

provisionally as natrolite, a conclusion which is, however, strengthened by the well-known tendency for nephelite to alter to natrolite. There are, throughout the section, small but constant amounts of a colourless, clear, isotropic mineral which occurs usually as interstitial grains reaching 0·5 mm. in diameter, but sometimes as irregular patches invading and even enclosing crystals of feldspar. The refractive index is very low—less than that of cancrinite—and there are very faint signs of cleavage. Chemical tests on the crushed rock indicate the presence of abundant chlorine, so that the mineral may be identified as sodalite. The ferromagnesian constituent is abundant aegirine in slender idiomorphic prisms about 0·5 mm. long (Fig. 3), strongly pleochroic, with Z = light brownish yellow, Y = deep green, and X = slightly deeper green. Some of the larger crystals and crystal clusters contain cores of pale, partially chloritised, greenish pyroxene. Iron ores are absent, but there are small prisms of apatite.

Duplicate sections of the same rock show several large crystals consisting of brown hornblende, rimmed with aegirine. One of these duplicates (S.W. 66a, in the Auckland University College collection) contains two interesting xenocrysts, which evidently originally consisted of olivine. One is 5 mm. in width, and has a central core of much shattered, slightly altered olivine, surrounded by a border 1 mm. in width, of fibrous talc mixed with a minor amount of pale chlorite. This in turn is bordered by a narrow fringe of fibrous bluish pennine, which passes outwards into an irregular rim consisting of small crystals of aegirine. The second xenocryst is only 2 mm. in diameter, and the central portion consists this time entirely of finely crystalline talc, immediately adjacent to which is a narrow, irregular fringe of colourless monoclinic pyroxene. This passes outward into a wide rim of hornblende, strongly pleochroic (pale reddish-brown to dark brownish-green), and having an extinction angle of 22°. This in turn is bordered with a well-defined band of dark green aegirine, adjacent to which the hornblende assumes a much deeper tint of brown. Bluish pennine is interspersed with the aegirine.

1293, Tinguaite. This is a fine-grained, light green rock with phenocrysts of feldspar reaching 5 mm. in length. It is holocrystalline and porphyritic, with abundant phenocrysts of feldspar and a few of pyroxene, set in a fine groundmass of feldspar, aegirine, and a little sodalite. The large feldspars are untwinned or simply twinned, with a lower refractive index than Canada balsam, and positive interference figure with an optic axial angle approaching 90°. They are therefore identified as albite-oligoclase. They are frequently flecked with calcite, and show marked undulose extinction. The feldspar of the groundmass is mostly of the same type, though a few lath-shaped individuals, showing the simple Carlsbad twin, may be orthoclase. Pale purplish, titaniferous augite, somewhat chloritised, forms rare phenocrysts, about 1 mm. in diameter, rimmed with dark green aegirine, while duplicate sections show occasional phenocrysts of aegirine-augite similarly bordered. Aegirine is itself abundant in

slender prisms 0·2 mm. long, with strong pleochroism (deep green to light brownish yellow), and small extinction angle. Orthopinacoidal twinning is rarely shown. There are a few small patches of finely crystalline (?) natrolite as in section 1294, probably representing original nephelite, while a little colourless sodalite is also present in the groundmass. Magnetite and apatite occur as minor accessories. Secondary calcite is plentiful throughout, for the most part occurring as an alteration product of the feldspar, while there are one or two small grains of secondary epidote.

II.—CAMPTONITES:

1295, Camptonite. The rock is holocrystalline, with the abundant ferromagnesian minerals and the panidiomorphic structure characteristic of the lamprophyres. The chief constituents are amphibole 40%, pyroxene 25%, altered olivine 10%, and partially altered feldspar 25%. Only pyroxene and olivine occur as phenocrysts. The pyroxene is pink titaniferous augite, and occurs both as plentiful stout idiomorphic, prismatic phenocrysts, 1 mm. to 2 mm. in length, and to a less extent as smaller, more irregular grains in the groundmass. In a few of the larger crystals, a central core of somewhat granular augite, intermixed with small ragged fragments of brown hornblende, is surrounded by a border of clear pink augite. On the other hand, several phenocrysts show a central, rounded crystal of aegirine-augite rimmed with normal pink pyroxene. The amphibole is barkevikite, and, like the pyroxene, is clear and unaltered. It forms short idiomorphic prisms about 0·2 mm. x 0·15 mm., with a maximum extinction angle of about 15°. It is strongly pleochroic, with X = light yellow, Y = deep reddish brown, and Z = deep brown (absorption X < Y < Z), while the birefringence is about 0·21 and the elongation is positive. The olivine originally present is completely decomposed, and is now represented by pseudomorphs consisting largely of pale green serpentinous material, with subordinate grains and rhombohedra of carbonate. The green mineral is almost uniaxial, negative, with positive elongation and moderate birefringence (about 0·015 to 0·017). It is identified as a ferriferous serpentine close to bowlingite. The feldspar occurs only in the groundmass, either interstitially or as small subidiomorphic crystals ranging up to 0·5 mm. in length. It is much altered to calcite and kaolin, and this, together with strongly undulose extinction prevent determination of optic sign and extinction angle. Traces of lamellar twinning, and a refractive index evidently higher than that of Canada balsam, nevertheless indicate that the feldspar is plagioclase. Granular magnetite and slender prisms of apatite are the only accessory minerals. Section 1295 shows a single irregular inclusion about 1·5 mm. x 1 mm., consisting of plagioclase with two sets of multiple twins, and coarsely crystalline secondary calcite. The negative optic sign of the feldspar, and the extinction angle of -68° (measured from Z to the basal cleavage) in a section perpendicular to the acute bisectrix X, correspond with basic bytownite. The whole inclusion is fringed by a reaction rim consisting of radially arranged prisms of aegirine-augite, with minor granules of pink augite. A duplicate

section shows another inclusion consisting of small crystals of indeterminate plagioclase and aegirine-augite, together with secondary calcite.

1296, Camptonite. A fine-grained, dark rock, in which small black prisms of amphibole and yellowish brown grains of olivine are clearly visible with the unaided eye. The chief minerals, as seen in section, are amphibole 30%, pyroxene 25%, olivine 15%, biotite 1%, feldspar 25%, analcite 3%, iron ores 1-2%. The structure is porphyritic, with large phenocrysts of olivine and smaller ones of amphibole and pyroxene, set in a groundmass consisting of all the minerals except olivine. The amphibole is strongly pleochroic, deep brown barkevikite which forms idiomorphic phenocrysts about 2 mm. in length, and also smaller, well-shaped crystals in the groundmass. Many of the phenocrysts have a deep brown, sharply defined central zone, surrounded by a border of lighter colour, but showing the same type of pleochroism. Several large phenocrysts (Fig. 1) have been almost completely converted into granular magnetite and pale greenish pyroxene, with residual barkevikite still showing in scattered fragments throughout. Such resorbed crystals have a very regular border of clear pink augite, and this in turn is irregularly edged with aegirine. The pyroxene is mainly pale pink augite in plentiful idiomorphic prisms averaging 0·5 mm. in length, and in grains of smaller size. Some of the larger phenocrysts have a sharply defined central zone of green aegirine-augite, while in others again the centre is pink augite and the border is colourless augite. A number of the smaller crystals of augite in the groundmass are rimmed with barkevikite, while others again show a narrow broken fringe of deep green aegirine. The latter mineral also occurs as irregular borders to some of the small barkevikites, and also as scattered individual grains in the groundmass. The olivine takes the form of large phenocrysts (reaching up to 5 mm.), which are clear and unaltered, except for occasional slight marginal transition to a pale green bowlingite. It is a normal magnesian olivine, with positive optic sign and fairly wide optic axial angle. The olivines are always bordered with reaction rims consisting of small crystals of barkevikite, biotite and barkevikite, or pink augite. Cracks in the phenocrysts, which have been penetrated by the reacting magma, are also filled with biotite and barkevikite. Biotite is also present in small amount throughout the groundmass as small subidiomorphic flakes with very pronounced pleochroism from light yellow to very deep brown (almost black). The feldspar includes both orthoclase, in slender simply twinned laths, and sodic plagioclase, the latter predominating. The plagioclase is much altered, but occasional traces of albite twinning and a refractive index less than that of Canada balsam can still be observed. A duplicate section shows a single large rounded xenocryst (2 mm. in diameter) of anorthoclase, with characteristic multiple twinning. The accessory minerals include apatite, pyrite, and small grains of magnetite. There is also a small amount (perhaps 3% or 5% of the whole rock) of clear, colourless isotropic material enwrapping the other minerals. When the crushed rock is boiled in nitric acid, treatment with silver nitrate solution indicates the presence of small

quantities of chlorine, such as might well be accounted for by the apatite content of the rock, and in no way comparable with the abundant chlorine which was indicated in the sodalite-bearing tinguaite No. 1294. It is probable then that sodalite is absent from the present rock, and the isotropic mineral is identified as analcite. This mineral is not sufficiently abundant, however, to warrant classification as a monchiquite.

1297, altered Camptonite. This is a fine grained, dark grey, somewhat mottled rock, which in section is seen to be a highly decomposed lamprophyre, the original constituents of which are amphibole 15%, pyroxene 20%, olivine 25%, feldspar 35%, magnetite 5%. The amphibole is brown barkevikitic hornblende, in subidiomorphic prisms about 0·5 x 0·1 mm., somewhat paler than the barkevikite of previous sections, but with the same general type of pleochroism. The pyroxene is pale pink augite, developed as small idiomorphic crystals with narrow borders of dusty magnetite. The large phenocrysts of olivine are now completely replaced by pseudomorphous masses of coarse carbonate, fine scales of talc and greenish fibrous serpentine. The feldspar occurs only in the groundmass. It is much altered to calcite and kaolin, and thus rendered indeterminate, though the presence of calcite suggests some variety of plagioclase. Small octahedrons of magnetite are plentiful in the groundmass.

1299, Camptonite. The section shows large phenocrysts of completely altered olivine, smaller ones of pyroxene, and occasional small crystals of hornblende and biotite, in an altered groundmass of pyroxene, feldspar, and iron ore. The large idiomorphic phenocrysts of olivine, constituting 10% of the section, are completely replaced by fibrous talc and small amounts of carbonate. The phenocrysts of pyroxene are, for the most part, idiomorphic crystals of bright green aegirine-augite, which are occasionally bordered with pale pink augite, itself edged with aegirine. There are also a few small phenocrysts of light yellow to almost black, intensely pleochroic biotite, and yellowish brown hornblende fringed with granular magnetite. Feldspar, which makes up about 30% of the section, is confined to the groundmass. It is greatly altered to sericite, kaolin, and calcite, but some crystals with refractive index higher than that of Canada balsam may definitely be determined as plagioclase. Altered pyroxene, some of which is aegirine-augite, also occurs abundantly in the groundmass, together with a minor quantity of biotite and plentiful grains of iron ore. A small percentage of colourless interstitial material, probably analcite, is present in some parts of the section. There are also numerous large prisms of clear apatite, some of which reach as much as 1·5 mm. in length. The only remaining constituent is a zeolite which occurs in clear aggregates, consisting of radially disposed or sometimes reticulated prisms about 0·5 mm. in length. It is colourless, or faintly clouded with alteration products, while the refractive index is lower than that of Canada balsam, but higher than that of analcite which sometimes occurs interstitially between the prisms of zeolite. The birefringence is about equal to that of the feldspar, the optic sign and elongation are negative, while the

extinction is inclined at about 5° to 8° to the direction of elongation. The elongation and oblique extinction indicate either scolecite or stilbite among the common zeolites. The extinction angle is, however, too low for scolecite (15° to 18°) and it is therefore identified as stilbite.

1298, Olivine-rich Camptonite. Megascopically this is a porphyritic rock, with very numerous light coloured phenocrysts which often reach 5 mm. in diameter, and constitute between 30% and 40% of the whole rock. In section, these are seen to be idiomorphic pseudomorphs after olivine, which is now completely replaced by finely granular carbonate, together with minor amounts of talc, serpentine, and secondary quartz. The groundmass is of much finer texture, contrasting sharply with the coarseness of the phenocrysts (Fig. 2), and consists, for the most part, of augite, hornblende, and feldspar, with minor iron ores. The augite occurs in pinkish or almost colourless idiomorphic crystals, which range from 0·1 mm. to 0·4 mm. in length, and usually show a narrow reaction border of reddish brown hornblende. Barkevikitic hornblende also occurs abundantly as small idiomorphic prisms. These are frequently terminated or fringed with a narrow rim of blue amphibole, which may also occur as scattered individual prisms and grains, and which is strongly pleochroic, with X = deep indigo blue, Y = lavender blue, Z = very pale lavender blue (absorption $X > Y > Z$). The elongation is negative, the extinction angle small (approximately 5°), and the dispersion strong (red > violet). This last factor, combined with the natural colour of the mineral, renders the exact determination of the birefringence difficult, but it is certainly low, and probably about 0·006. The mineral is evidently a sodic amphibole very close to riebeckite, from which it differs only in its slightly high birefringence (riebeckite has 0·004) and paler absorption tints. The remaining minerals are feldspar (probably plagioclase), which is much altered to calcite, and numerous ragged grains of iron ore, best referred to ilmenite. The proportions of the two main ferromagnesian constituents of the groundmass vary widely, even within the limits of a single section. Feldspar always makes up about 30% of the groundmass, but whereas in some parts brown hornblende is the dominant mineral, in others it is almost absent, while the proportion of augite is correspondingly increased. While this rock is essentially similar to those just described, it differs in the great abundance of large phenocrysts of olivine.

S.W. 61 (Auckland University College collection), Olivine-rich Camptonite. This very closely resembles the previous rock (1298), and was collected from the same locality. At least 50% of the rock consists of large idiomorphic pseudomorphs after olivine, sometimes attaining 10 mm. in diameter. In one or two crystals, where a central core of unaltered olivine still persists, the lines along which alteration has proceeded may be observed. First of all fine strings of magnetite are thrown out along the cracks, which become bordered with finely granular carbonate, thus developing a pronounced mesh

structure. The olivine remaining between the meshes is now converted into talc, so that the mesh structure is preserved in the completed pseudomorph, while sometimes both talc and carbonate ultimately become more coarsely crystalline. Many of these altered olivines are crossed by narrow veinlets of transversely fibrous bluish-green chlorite, which seems to be allied to bowlingite as defined by Winchell (1928, p. 382). Though the outline of the olivine phenocrysts is usually strikingly idiomorphic, there is nevertheless evidence of considerable reaction between the phenocrysts and the liquid magma which is now represented by the groundmass. Frequently the liquid has forced its way along cracks, so that small angular fragments have been broken off the large crystals and strewed through the groundmass in their immediate neighbourhood. In yet other instances, the liquid has eaten its way along cracks and ultimately solidified as "inclusions" within the phenocryst, connected with the groundmass by narrow veinlets now largely filled with chloritic material. These "inclusions," representing the solidified reaction product of olivine and liquid, always contain abundant prisms of golden-brown hornblende, which are enclosed in either the bluish-green chlorite mentioned above, or else in a colourless isotropic base which is probably analcite. A little feldspar is sometimes present. In addition to the large olivines there are also a few much smaller phenocrysts of partly chloritised titaniferous augite, about 0·5 mm. to 1·5 mm. in length. The remainder of the rock is a fine groundmass, consisting of tiny prisms of golden-brown hornblende, a somewhat less amount of pale pink augite, small crystals of altered indeterminate plagioclase, and plentiful magnetite. Secondary flakes of kaolin, talc, and calcite are abundant. As in the previous section, the distribution of ferromagnesian minerals is irregular, some portions of the section consisting almost entirely of hornblende and feldspar. There is a single xenolith about 6 mm. x 3 mm., consisting of irregular grains of quartz, the whole being bordered by a narrow zone of serpentine, talc, and magnetite.

1300, Heterogeneous augite-camptonite. Under the microscope this rock presents a curious heterogeneous appearance since the mineral composition of the rock is not uniform, but is of two distinct types without intermediate gradation (Fig. 4). In the two sections examined, about 60% of the whole rock is a holocrystalline mass, of which the chief constituents are augite 60%, olivine 10%, hornblende 10%, feldspar 10%, and biotite and magnetite about 5% each. The idiomorphic phenocrysts of olivine (1 mm. to 3 mm. in diameter) are now entirely replaced by talc and a little granular carbonate, which in some cases outlines the original cracks, thus imparting a rough mesh structure to the pseudomorph. Pale violet augite occurs both in rather small clear idiomorphic phenocrysts about 1 mm. in length, and also as very numerous smaller prisms and grains which occasionally are bordered with hornblende. In one phenocryst, a central core of aegirine-augite was noted. The hornblende is pale yellowish brown to deep golden brown, in small idiomorphic prisms, frequently showing the orthopinacoidal twin, and having a maximum extinction angle of about 15°. The biotite is also in small flakes with

intense pleochroism from very pale yellow to deep reddish brown. It is somewhat rare in section 1300, but much more plentiful in a duplicate section (S.W. 62, in the Auckland University College collection). The feldspar is almost completely altered to a highly birefringent aggregate of kaolin, sericite, and calcite. Granular magnetite is abundant, and there are a few small prisms of apatite. The second type of mineral association is developed in numerous, often sharply defined areas, about 2 mm. to 5 mm. in diameter, enclosed by the crystalline mass just described. It consists mainly of light coloured, semi-opaque highly birefringent material which appears to be kaolin mixed with smaller amounts of calcite and sericite, and thus probably represents original feldspar, occasional fragments of which may still be observed. The ferromagnesian constituents are brown hornblende and biotite either singly, or associated in widely varying proportions. They form slender crystals which sometimes exhibit a tendency towards radial arrangement, and are often fringed with borders of dusty magnetite. Augite and primary magnetite are quite absent, though small fragments of altered olivine are present in one or two places. These leucocratic patches no doubt represent the solidified reaction product of a residual magmatic liquid, which has occupied the interspaces of a loosely aggregated mass of accumulated crystals rich in olivine, augite, and magnetite, and which has solidified there in reaction with the surrounding crystals. Flett (1911, p. 90; pl. 6, fig. 3) describes and figures "ocelli" of similar nature in the analcite-bearing camptonites of the Ross of Mull. These "ocelli" are described as rounded or oval spots, up to half an inch in diameter, consisting of radiate feldspars, long brown hornblendes, and less numerous crystals of augite, while, as in the section described above, there is also a small amount of interstitial analcite. The same writer (Flett, 1908, p. 125) refers to similar "ocellar" patches in the Tertiary camptonites of Oban.

MUTUAL RELATIONSHIP OF TINGUAITES AND CAMPTONITES.

Various lines of reasoning indicate that the tinguaites and camptonites of the Haast and Makarora Valleys are intimately related rocks, representing different stages of the same differentiation series. In the first place, all are found in a restricted area, many miles from any other centre of igneous activity, the nearest igneous rocks being the granite-pegmatites which occur at the mouth of the Haast River, some twenty miles westward. In the second place there appears to be regular gradation between the extreme types. Thus, while large phenocrysts of altered olivine are a constant and conspicuous feature of the camptonites, so also the highly alkaline cancrinite-tinguaite No. 1924 occasionally contains large xenocrysts of olivine similarly altered. Again there seems to be a gradation between the tinguaites with abundant aegirine, through camptonites such as No. 1299, containing plentiful phenocrysts of aegirine-augite, to more typical camptonites in which the pyroxene is mostly augite, aegirine and aegirine-augite being present in very small proportions only. On the

other hand, barkevikite, which is such an abundant constituent of the camptonites, is also represented as occasional clusters and xenocrysts in the tinguaites. Finally an extensive series of similar rocks described by Smith (1908) from northern Westland is said to show a perfect sequence from tinguaites to lamprohyres (Smith, 1908, p. 126).

It is thus evident that tinguaites and camptonites alike have originated from a common source, and any theory of origin must account for the presence of both types of rock.

COURSE OF CRYSTALLISATION OF PARENT MAGMA.

Writing with reference to the origin of lamprophyres, Bowen (1928, p. 258) states that Niggli and Beger (1923, pp. 571-574) " conclude that these rocks are accounted for by local accumulation of early crystals, which have then remelted or redissolved, and given a liquid of lamprophyric composition." In criticising the above suggestion, Bowen (1928, p. 258) then points out that the porphyritic and panidiomorphic structures so characteristic of the lamprophyres, are themselves strong evidence against the existence of lamprophyric liquid.

The camptonites of the Haast and Makarora Valleys all contain plentiful large phenocrysts of olivine, which in some specimens are so numerous as to constitute at least half the total composition of the rock. Now Bowen (1928, pp. 159-164) has conclusively demonstrated that magmas never contain more than some 12% to 15% of normative olivine. It therefore follows that liquids having the total composition of these camptonites could never have existed, and the high olivine content must be due to crystal accumulation. As will be shown later, there is abundant additional evidence that crystal sinking and accumulation have played an important part in the evolution of the camptonite-tinguaite series.

Bowen (1928, pp. 258-268) has outlined a theory according to which the olivine-bearing lamprophyres have originated as a result of reaction between an alkaline magmatic liquid and accumulated crystals of femic minerals, notably olivine and augite. In a subsequent chapter (1928, ch. 14), he suggests that this association of alkaline liquid and femic minerals is by no means fortuitous, but " is believed to be due to the fractional resorption of complex minerals, notably hornblende," which he pictures as sinking into a relatively hot basaltic magma from higher levels.

In a later section, it will be shown that the facts at present available suggest that the camptonites and tinguaites of Westland are considerably younger than the great series of peridotites, diorites, and granites which are so plentifully developed in that province. There are therefore not sufficient data to warrant speculation as to the ultimate source of the parent camptonite-tinguaite magma, nor as to whether fractional resorption of hornblende has been an important factor in its production. There does seem, however, to be

sufficient evidence to indicate that the camptonites and tinguaites have arisen as a result of differentiation of a highly sodic magma rich in ferro-magnesian constituents, from which abundant crystals of olivine had already separated. In the subsequent paragraphs an attempt will be made to outline this differentiation process, as deduced from the petrographic characters observed in the rocks in question.

During the initial stages the main feature was continued separation of olivine crystals, the large size of which suggests that this process continued for a considerable time. As a result of continuous settling of the first-formed crystals, the lower portion of the magma became much enriched in olivine, while the upper levels were impoverished in this component and correspondingly enriched in the increasingly alkaline residual liquid.

With falling temperature, a stage was at last reached when reaction between olivine and magma set in, with resultant precipitation of colourless or pale pink augite, reaction rims of which sometimes border the olivine phenocrysts. Precipitation of augite continued further until a temperature was reached when the augite and magma began to react to produce amphibole, which, as a result of the high soda-content of the reacting magma, took the form of the soda-rich variety barkevikite.

Olivine, augite, and barkevikite are all represented as phenocrysts in the rocks under consideration, but later products of the femic reaction series are represented only as reaction rims bordering the phenocrysts, or as constituents of the groundmass. These later members were therefore apparently formed as a result of reaction during rapid cooling following upon injection of the magma as dykes. The general reaction sequence appears to be olivine $\rightarrow$ augite $\rightarrow$ barkevikite $\rightarrow$ aegirine or biotite. A certain amount of variation is introduced by differences in composition of the liquid throughout the mass. Thus aegirine-augite may appear in certain of the more alkaline rocks (e.g., as phenocrysts in No. 1299), but whether or not it precedes the formation of barkevikite is uncertain. It certainly appears after normal augite, and before aegirine, but so also does barkevikite (e.g., in section S.W. 66a, a duplicate of the tinguaite No. 1294, one of the large xenocrysts of altered olivine shows perfectly the reaction series olivine $\rightarrow$ augite $\rightarrow$ barkevikite $\rightarrow$ aegirine). In another rock, section 1298, sodic amphibole very close to riebeckite was formed at a late stage by reaction between barkevikite and the liquid. The last ferromagnesian silicates to be formed are aegirine, biotite, or both. These are never abundant except in the tinguaites, where aegirine is the predominant femic constituent. No doubt the factor determining their crystallisation was relative abundance of soda and potash in the residual liquid when crystallisation was nearly complete.

As a result of different rates of cooling and variation in total composition throughout the magma mass, it is obvious that at a given moment different stages in the above reaction sequence would be reached in different parts of the mass. Thus augite might still be

separating in the lower portion, at a time when at higher levels, where olivine has disappeared, aegirine-augite or barkevikite would be the stable solid components in equilibrium with the corresponding liquids. Consequently, to complicate matters further, sinking crystals of aegirine-augite and barkevikite would find their way into liquid where normal augite was still separating out. Reversal of the normal reaction sequence would then result as pictured by Bowen (1928, pp. 275-276). The results of such a process would be for the most part confined to the larger phenocrysts, while the crystals of the groundmass would be expected to indicate the normal reaction sequence.

Section No. 1296 is a good example of a rock in which the normal and reversed reaction sequences have both been developed. The normal reactions observed are olivine → augite, olivine → barkevikite, and olivine → biotite, shown by the large phenocrysts of olivine; augite → aegirine, shown by phenocrysts and small crystals of augite; augite → barkevikite → aegirine shown by small crystals in the groundmass. Reversed reactions, plainly shown by large, partially resorbed crystals of barkevikite and others of aegirine-augite, are barkevikite → augite and aegirine-augite → augite. These large partly resorbed barkevikites also show the results of the normal reaction augite → aegirine, which expresses itself in an outermost fringe of aegirine, formed at a late stage in crystallisation, simultaneously with the separation of aegirine in the groundmass.

The reversed reactions described above are also illustrated by a few of the phenocrysts in Section No. 1295. In Section No. 1299, the large phenocrysts of aegirine-augite are bordered with a narrow rim of colourless augite, representing reversal of the normal reaction, and this in turn is surrounded by an irregular outer rim of aegirine indicating the normal reaction augite → aegirine at a late stage in crystallisation.

Injection of the partially crystallised magma as dykes took place when the parent mass was in the heterogeneous condition described above. Dykes drawn from the higher levels would be of tinguaitic composition, while those emanating from the lower portions of the mass would be olivine-rich camptonites.

In the tinguaites, aegirine, though abundant in the groundmass, is not developed as phenocrysts; on the other hand the presence of large phenocrysts of albite-perthite indicates that in the upper levels from which the tinguaites were drawn, the magma had already attained, prior to intrusion, a composition such that alkali-feldspar had commenced to crystallise. In the camptonites, on the other hand, feldspar is confined to the groundmass. Camptonites such as Nos. 1296 and 1299, in which partially resorbed phenocrysts of barkevikite and aegirine-augite from the higher levels still persist, in addition to the usual abundant olivine and augite, represent magma drawn from intermediate levels. Those camptonites in which olivine is extremely abundant (e.g., No. 1298), and the augite-rich variety, No. 1300, doubtless represent the lower portion of the magma where

Fig. 1.—Camptonite (1296) showing phenocrysts of barkevikite set in a groundmass of augite, barkevikite, and altered feldspar. The large dark crystal is a resorbed barkevikite rimmed with clear titan-augite. Magnification, 40 diams.

Fig. 2.—Olivine-rich Camptonite (1298). Large altered crystals of olivine are enclosed in an extremely fine crystalline groundmass (black). Magnification, 15 diams.

Fig. 3.—Tinguaite (1294) showing dark prismatic crystals of aegirine enclosed by light-coloured cancrinite and feldspar. Magnification, 40 diams.

Fig. 4.—Augite-rich Camptonite (1300). An "ocellar" patch of altered feldspar and analcite with scattered crystals of barkevikite and biotite (lower left), is partly surrounded by a granular aggregate consisting largely of augite and magnetite, which constitutes the normal groundmass of the rock. Magnification, 40 diams.

(All photographs taken in ordinary light).

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accumulation of early-formed crystals has been effective. It is of interest to note that even here, the interstitial liquid was sufficiently alkaline for biotite, riebeckite, and analcite to be formed among the final products of crystallisation.

An interesting feature of some of the more basic olivine-rich and augite-rich camptonites is the heterogeneous nature of the groundmass already referred to in a previous section. This is most striking in No. 1300, where "ocellar" patches are developed (Fig. 4), comparable with similar structures observed by Flett (1908, p. 125; 1911, p. 90) in some of the Tertiary camptonites of Scotland. The injected material, in the case of No. 1300, must have consisted of crystalline augite and olivine, with about an equal quantity of liquid scattered as globules throughout the interstices of the mass. Rapid cooling following on injection, brought about complete solidification of the liquid, before complete reaction with the olivine and augite had been affected. The liquid is now represented in the resultant rock by conspicuous "ocellar" aggregates of feldspar, radially disposed hornblende and biotite, and interstitial analcite, surrounded by a mass consisting almost entirely of augite, olivine, and magnetite, the products of early crystallisation.

Bowen (1928, pp. 270, 271) stresses the importance of filtration and squeezing out of liquid from crystals during injection, as a means of producing a nepheline-rich liquid from such a magma as we have been considering. In the case of the Haast-Makarora rocks, it is probable that this process was of minor importance only. It has already been shown that crystal-sinking prior to injection of the dykes had a profound influence on the differentiation of the series. On the other hand, the presence in the tinguaites of large phenocrysts of feldspar, obviously the result of crystallisation before injection, and the presence of "ocellar" patches in the more basic camptonites indicating that abundant liquid was still interspersed throughout a spongelike mass of crystals after injection, are both facts which suggest that the squeezing-out process was not an important factor in determining the present constitution of the rocks under consideration.

CORRELATION AND AGE.

Many varieties of lamprophyres and related basic hypabyssal rocks have been recorded from localities in West Nelson and North Westland, ranging from Reefton in the north to Hokitika district in the south (Bell and Fraser, 1906, pp. 82, 83; Smith, 1908; Morgan, 1908, pp. 138, 139; Morgan, 1911, pp. 80, 81; Bartrum, 1914, pp. 267, 268; Henderson, 1917, pp. 107, 108). The prevailing types are hornblende- and augite-camptonites, which grade into porphyrites and diabases, or with the development of analcite pass into monchiquites. Other varieties are also present, especially in the Reefton district, where Henderson (1917) has described minettes, kersantites, vogesites, spessartites, camptonites, and diabases.

Probably the most interesting series of dyke rocks from this North Westland region is that described by Smith (1908) from stream boulders collected from New River in the vicinity of Greymouth. According to Smith, there is complete gradation between tinguaites with abundant cancrinite, nephelite, and aegirine, and camptonites and vogesites in which, though feldspathoids are absent, barkevikite and aegirine indicate alkaline affinities. From the same area Smith also describes gabbros, diabases, and theralites, while undescribed specimens subsequently presented by the same writer to the Geological Museum of the Otago University include a coarsely crystalline ditroite in which blue sodalite is clearly visible in the hand specimen.

The Haast-Makarora area lies about 150 miles south of the district studied by Smith. Nevertheless there is a striking similarity between the tinguaites and normal and aegirine-bearing camptonites of these two widely separated localities.

Park (1909) noted hornblende-camptonites and monchiquites from the Shotover and Kawarau Valleys in the Lake Wakatipu district, some 50 miles south-west of the present area. While strongly alkaline types are not included among these rocks, they are nevertheless closely similar to the normal camptonites of Westland. An augite-hornblende-monchiquite from the Shotover in the Otago University collection (La. 13) resembles Section No. 1300 described above, in that there is a tendency towards heterogeneous composition, resulting from concentration of augite or hornblende in different parts of the section.

Some difference of opinion at present exists as to the exact age of the basic dyke rocks of Nelson and Westland. Bell and Fraser (1906, p. 82) give the age of rocks of this type in the Hokitika district as probably early or mid-Tertiary. Morgan and Bartrum (1915, p. 104) state that dykes of camptonite and monchiquite not only invade the ancient greywackes, schists, and intrusive granites, but even penetrate the lower beds of the unconformably overlying Eocene coal-measures. They suggest an early Eocene date of intrusion. Henderson (1917), while recognising that the camptonites and some of the dolerites of the Reefton district are early Tertiary, nevertheless states that the diorites and vogesites of that area followed immediately upon the granite intrusions of the (?) Early Cretaceous, while some of the dolerites even antedate the period of granite intrusion.

The evidence available indicates that many of the basic dyke-rocks of the West Coast region, including camptonites, monchiquites, and tinguaites, were injected probably in Early Tertiary times. The rocks of this group are thus considerably younger than the great intrusions of peridotite, diorite, and granite, which, according to most authorities (e.g., Henderson, 1917, p. 104) accompanied the profound mountain-building movements of the Early Cretaceous. It is therefore probable that the petrographically similar tinguaites and camptonites of the Haast-Makarora area, which have not been appreciably affected by stress, post-date the Lower Cretaceous orogeny.

ACKNOWLEDGMENTS AND THANKS.

The rocks which form the subject of this paper were collected during February, 1930, in the course of an expedition into the extreme south of Westland by way of the Makarora and Haast Valleys and Haast Pass. A large part of the expense incurred was defrayed by a grant from the Otago University Council, to which body I am much indebted.

My thanks are also extended to my companions, Professor J. A. Bartrum, of Auckland, and Messrs G. Simpson, and J. S. Thomson, of Dunedin. I am also much obliged to Professor Bartrum for the loan of duplicate sections cut by him from rocks collected in this locality; to the Cawthron Institute for loan of sections for comparison; and to Dr B. Dodds, of the Otago University Dental School, for use of photomicrographic apparatus.

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An Ecological Study of the Vegetation of the Cromwell District, with Special Reference to Root Habit.

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[*Issued separately, 31st March, 1932.*]

CONTENTS.

*INTRODUCTION.

That the subterranean parts of plants possess a configuration which is just as characteristic of the species as the more familiar sub-aerial portions, is increasingly being recognised. The labour involved in making proper observations upon roots has naturally discouraged their examination, but it will be apparent that the fuller knowledge of plants which is afforded by a study of their root habit should make for more thorough understanding of their ecological relations. Weaver (1919, p. 1) has pointed out that, "A knowledge of root distribution and root competition under different natural conditions, is not only of much scientific value, but it also finds practical application in a better understanding of the value of plants as indicators for distinguishing lands of grazing value only, from those with

*The author's thanks are due to the Rev. Dr John E. Holloway, not only for his original suggestion of the subject, but for his aid and criticism throughout.

possibilities of crop production. It will result in a more intelligent solution of the ecological problems of grazing, and will likewise be of great aid to the forester in selecting sites for afforestation. Moreover a knowledge of root distribution will throw a flood of light upon many problems of succession. Indeed, the phenomena of ecesis, competition, and reaction cannot be completely, if indeed correctly interpreted, without a knowledge of the extent, position, and relation of the root-systems of the plants."

The area considered in this study is that part of the Upper Clutha Valley lying around Cromwell and Lowburn Ferry, Central Otago (Fig. 1). It was selected for study for the special reason that it is fairly representative of a much larger area of Central Otago, which experiences the driest climate of any region of New Zealand. Reference to Figure 2, which shows the average annual distribution of rainfall over the South Island, will give an indication of the approximate location and extent of this larger area. The area dealt with in the present study is situated in the neighbourhood of Cromwell, Clyde, and Alexandra, and has been referred to by various authors as the "*depleted area.*" At Clyde, the average annual precipitation is about 15 inches, while near Alexandra it is still lower. Originally, the land was covered by a close tussock vegetation, but owing to the influence of biotic factors introduced some sixty years ago, the district now presents an aspect of semi-aridity.

The main purpose of this investigation was to make a study of the root-systems of some of the more common plants of the district, with a view to relating the information so gained with the problems of succession and distribution.

PREVIOUS WORK.

The only noteworthy ecological observations upon the locality under review are those contained in a series of articles by L. Cockayne, in the *New Zealand Journal of Agriculture,* under the title of "An Economic Investigation of the Montane Tussock Grassland of New Zealand." As the title suggests, the paper was written from an economic rather than an ecological standpoint, and a description of the vegetation of the north face of the Dunstan Range forms but a part of it. For the purpose of the present study, this paper, however, has been very useful. The same author gives a short account of the "transformation of steppe into induced-desert," in *Die Vegetation der Erde,* vol. 14, p. 289. Valuable information with regard to the habit and anatomy of the above-ground parts of some of the plants dealt with has also been obtained from papers by Foweraker (1917), and also by Miss Betts (1919).

In New Zealand, no recorded systematic work has previously been carried out upon the root habit of indigenous plants. It must be emphasised, however, that such information as has been gained by the present study is but a small beginning. Before generalisations can be made, a larger number of individuals of each species should be examined in different stations, as well as a greater variety of

species. The nature of the work entailed is distinctly arduous, and the difficulties of working single-handed at such a task will be appreciated.

EXPERIMENTAL PROCEDURE.

METHOD OF EXAMINATION OF ROOTS:

The method adopted was largely that described by Weaver (1919, p. 2). A trench was dug alongside the selected plant, about 2 to 3 feet wide, 9 to 15 feet long, and to a depth of about 6 feet. Thus an open face was exposed, from which the root-system could be dissected with a small trowel and a spike made from a piece of stout fencing wire. Thus the roots present in a vertical section about 4 to 6 inches wide, 9 to 15 feet long, and 6 feet deep could be examined. This is taken as representative of the whole system (Fig. 3).

As Weaver states, extreme care must be observed in excavating root termini, to ascertain their maximum depth. To ensure this, the soil was undercut some inches below the deepest roots and carefully examined as it was removed.

Various practical difficulties had to be surmounted. In the first place, to avoid confusion with the roots of neighbouring plants of the same species, or even of other species, the specimen examined was selected generally in a more or less isolated position. Anyone who has seen the close manner in which plants of *Raoulia lutescens* grow in suitable stations, will appreciate the difficulty involved in excavating a root-system of a single plant distinct from others in such a station.

As the work had to be done as expeditiously as possible, it was important that plants growing in easily workable soils should be selected. Obviously it would be a hopeless task to excavate the root-system of *Raoulia lutescens* growing on the very rocky Dunstan Mountains. Accordingly, specimens selected were for the most part growing upon the gravel terraces which characterise the valley of the Upper Clutha River. These terraces attain a great thickness and vary in the size of the stones composing the gravel of which they are composed. The gravel in some terraces is very unstable, and the formation of gulches is of common occurrence.

Considerable difficulty was experienced from caving of the loose sandy gravel. In some cases, excavation beyond a certain depth had to be abandoned on this account.

Weaver (1919) has shown that different soil habitats modify the root systems of many plants. Thus it must be borne in mind that the characters of the roots illustrated are not necessarily of general occurrence, although it is fairly certain that where the soil offers no serious obstruction to the roots in the form of rocks, hard-pans, etc., the general configuration of the various systems will be similar to those described.

General:

As the district is situated some 142 miles by road from Dunedin, only periodic visits could be made to it. The observations extended over a period of seven months, from the end of February to the beginning of September, 1928, too short a time in which to make a complete investigation. During this period four visits were made to the locality. These were on the following dates:

February 24 to March 1.
April 16 to April 20.
May 26 to June 6.
August 25 to September 1.

The order followed in this paper will be a description of the root habits of a number of plants, followed by an account of the environmental conditions under which they grow. These considerations will then be incorporated into a brief account of the communities and their distribution, together with some observations upon the above-ground parts of the plants.

THE ROOT HABIT OF VARIOUS SPECIES.

Poa caespitosa Forst.

The wide distribution of this grass together with *Festuca Novae-Zelandiae* Cockayne throughout New Zealand—a country of very diverse climates—indicates that these grasses can apparently thrive under a variety of environmental conditions. The characteristic "tussock" growth form is a feature which it possesses in common with a number of other indigenous grasses. (Cockayne, 1921, p. 107 and p. 167).

The larger specimen figured,* (Fig. 6) was excavated on May 27. It was growing on slightly inclined ground, subjected to the slow accumulation of wind-blown sand. Consequently the upper 9 inches of soil was almost pure sand, and this overlaid a considerable depth of sandy gravel containing many water-worn stones of various sizes, up to the size of an egg. In this and other specimens excavated, the grass is characteristically shallow-rooted, rarely penetrating beyond three feet. The lateral extension, however, is fairly wide, the roots in some cases reaching out to a distance of about three feet from the basal culm. The main roots are about 1 mm. in diameter at their origin, pale brown in colour, and remain more or less uniform in diameter throughout their length, ending more or less abruptly. The character of the soil modifies considerably the character of the roots. In this plant, in the upper 9 inches, where the soil was almost pure sand, the main roots pursued a more or less straight course without much bending or kinking. The laterals borne upon this region were short ($\frac{3}{4}$-inch long) and numerous, arising from the main root almost at right angles to it. These laterals carried smaller rootlets which,

*In all drawings of root systems, the squared lines represent distances of one foot.

however, were very rudimentary. In the lower region, as soon as the roots entered the stony gravel, they became more bent, probably consequent upon the necessity for bending around the stones. The laterals of the first order were here longer than those in the upper 9 inches of soil, reaching a length of 3 to 4 inches, and they carried laterals of the second order which were better developed than those of the upper region.

The soil immediately below the surface was filled with a compact mass of fibrous roots.

Figure 7 illustrates the root system of a plant growing upon the Cromwell Flat adjoining Cromwell township. The upper 9 inches of the ground was composed of a light-coloured soil, which passed abruptly into a fine gravel. The lateral extension of the roots is here well evidenced, many of the roots pursuing an almost horizontal course for about two feet before turning gradually downwards. A striking feature here was the presence of a number of new roots induced by fairly heavy rain after a sustained drought. These roots were about 2 mm. in diameter, and possessed a thick, white slimy cortex, which rubbed off easily. Laterals were quite absent from them, but presumably these would appear when the roots became older. This plant was excavated on May 28.

Figure 8 shows the development of the roots of a specimen growing on the face of a terrace. The habitat was one of extreme mobility. The angle of slope was about 30°, and consequently the crown of the plant was continually subjected to a constant pressure exerted by the upper layer of gravel, slowly sliding down the slope. The response of the plant in the development of anchoring roots to withstand this pressure is striking. All the roots carried a profuse covering of laterals about ¾-inch long, the whole system being well adapted to absorption from the surface soil. (To avoid complexity, the laterals have been omitted from the figure). The depth of penetration at right angles to the surface was not more than two feet. The development of a surface root-system and also anchoring roots are characters found by Weaver (1919) in his investigation of the gravel slides of the Rocky Mountains.

Cockayne (1921, p. 167) asserts that " when on dry ground, (the tussock's) long, deeply-descending roots reach the ground water, while its numerous short ones passing into the water-absorbing dead leaves at its base can take advantage of even brief showers." That absorption may take place from the dead leaves is not doubted, but the statement that the tussock produces deep roots which absorb moisture from the ground-water seems incorrect. Four specimens were examined, and in no case did the roots descend lower than 3 feet 6 inches, nor were they observed to reach the ground-water.

Raoulia lutescens Beauv.

On the depleted slopes of the Dunstan Range, this plant is the most conspicuous feature of the landscape, and at first sight appears to be in almost sole possession. Foweraker (1916) describes its growth-form as a true " cushion " (Fig. 5). Owing to the very

rocky nature of the soil, it was found extremely difficult to excavate a root system satisfactorily on the Range, and accordingly two plants growing on the lower terraces were examined. The plants in each case were about 2 feet in diameter.

The extent of the root-system is surprising, considering the relatively small amount of leaf surface which the plant exposes, and the intensely xerophytic nature of the above-ground parts. The soil in which the specimens examined were growing was a light gravel containing much sand of a very absorbent nature. The soil directly underneath the plant was packed with slender adventitious roots. These roots are brown in colour, about 1 mm. in diameter near the surface, and very brittle. They taper imperceptibly towards their termini, ending in a well-developed branch system, the branches being produced to the second and third order. The lateral extension is not great, but the depth to which the roots penetrate—about 6 feet—is no doubt a very important factor in the water economy of the plant. It is evident from Figure 9 that the root development is extensive, exposing a large absorptive surface. This character of the root-system, combined with the reduced and protected leaf surface, has no doubt been the chief means in determining the dominance of *Raoulia lutescens* throughout the "arid" areas of Central Otago. At the time the examination was made (April 18), a comparatively heavy three days' rain had fallen, following on a five months' virtual drought. The sustained drought had caused almost all plants except the Raoulias to become desiccated. The latter still retained their usual glaucous green appearance.

In the second specimen examined, two months later (June 4), some of the roots in the upper soil carried small bunches of rudimentary roots (Fig. 10). These peculiar rootlets may have been developed for absorption of the surface moisture which had accumulated at this time. Repeated examination at subsequent intervals would prove whether or not these rudimentary roots are deciduous.

The complete possession of the soil by the roots of this species, must, and does set up considerable competition with the roots of individuals of the same species and also of other species. Where the plants are more or less scattered, as on the terraces, this effect can be seen in the more stunted growth of the smaller annuals and perennials in a concentric ring immediately around the plant. (Fig. 4).

Carmichaelia Petriei T. Kirk.

The leafless nature of this leguminous plant at once indicates it as a special xerophyte. The cylindrical cladodes are sparingly branched, and the plant generally attains a height of about 4 feet. It is not very common in the district under review, but owing to its remarkable root-system and obvious xerophytic structure, a number of specimens were excavated. An idea of the appearance of the plant can be obtained by reference to Figure 3.

The root development of a specimen about 3 feet in height is shown in Figure 11. The soil consisted of light sand to a depth of 4 feet. The upper three feet was damp at the time of examination

(April 19), due to recent rains, and this was succeeded by a foot of perfectly dry sand. At the 4-feet level there was a stratum of fine damp gravel, which fell away easily, presenting no difficulty for penetration by roots.

The plant possessed a main taproot about 1½ inches diameter at the top. The branches of the plant joined the root below the ground level, forming a multicipital crown. At a depth of 18 inches, the taproot divided into two equal branches, one of which could not be followed. The other continued downwards to a depth of 4 feet, where it turned abruptly in a horizontal direction. From the taproot in its uppermost 18 inches arose six main laterals which all pursued an almost horizontal course for about two feet, when they turned downwards abruptly, taking a vertically downward direction to a depth of 4 feet, when all took a horizontal course. This sudden deviation of the roots at the 4-feet level is striking, and is coincident with the stratum of damp sand which occurred at this level. This damp layer was doubtless the capillary fringe of the water-table. (The capillary fringe is defined as that stratum of soil immediately above the level of the standing water-table, into which the water rises by capillary attraction). At a distance of about a hundred yards from the position of the plant was situated a small artesian well, which by its constant flow may have maintained the water-table at a fairly constant height. The coincidence of the horizontal extension of the roots with the damp layer might be interpreted as a response on the part of the roots to the special conditions obtaining. Possibly a response to the stimulus of water was in evidence, or lack of aeration at greater depth may have determined the condition.

All the upper portions of the main roots showed little branching. The main mass of absorbing roots was at the 4-feet level, where profuse bunches of roots branched to the third order were situated. A number of small roots were, however, produced from the taproot in its upper portion. The roots are rich brown in colour, quite tough and flexible. The horizontal root at the left of Figure 11 was followed for a further distance of 3 feet before it was finally lost.

In Figure 12 is shown the root-system of another specimen growing in a similar type of soil. A glance at the figure will show that the lateral extension of the roots is far greater than in the first specimen, for here they were found to extend horizontally to a distance of 9 feet. A ground plan of this development is seen in Figure 13. A taproot is again present, but here it turned sharply to the left at the 2-feet level, a smaller branch of the main root continuing vertically downwards to a maximum depth of 5 feet 6 inches, after having divided into a number of smaller branches. Although the lateral root to the right of the figure showed considerable horizontal extension, it eventually turned abruptly downwards at a distance of 9 feet from the base of the plant. The horizontal extension of the taproot to the left was lost at a distance of 9 feet from the crown of the plant. There was found to be no definite damp stratum in this case, the soil becoming imperceptibly damper from a depth of 4 feet 6 inches downwards. Possibly in this spot the level of the

capillary fringe was subject to fluctuation, which would account for the absence of a constant depth of turning to a horizontal course as exhibited by the roots of the previous example.

Figure 14 illustrates the root-system of a plant which grew on the edge of a steep terrace. The habitat was one of extreme exposure, and the level of the ground to one side of the plant sloped sharply downwards at a steep angle. It could reasonably be assumed that in such a position the water-table would be far below the surface, and that the roots would necessarily depend upon water percolating from the surface. The plant showed the same development of a taproot, and a system of laterals which after traversing a variable horizontal distance, eventually turned sharply downwards. This feature would seem therefore to be a constant one, modified to a different extent in different localities. In accordance with the absence of a definite damp layer, there was found to be no definite depth of absorption. The soil was actually of a similar degree of dampness at all depths (there had been recent rains), and apparently absorption took place at any depth. The development and distribution of the finer absorbing bunches of rootlets, as shown in the figure, was in accordance with this conclusion.

On both the last two specimens, a number of adventitious roots were developed from the multicipital crown of the plant.

The very characteristic configuration of the root-system of this species is seen also in *C. subulata* T. Kirk, a species very similar in growth form to C. Petriei, but having more slender cladodes. A specimen was found growing on the edge of a disused sluicing pit, and by removing some of the face of the cliff, the roots were exposed. The same development of taproot and horizontal laterals which eventually turned abruptly downwards was again present. In this case, however, the depth of penetration was much greater, for at a depth of 10 feet, the roots were still 3 mm. in diameter. In such a position, the water-table would naturally be very low.

The horizontal extension of the lateral roots at a depth of six inches to two feet was thus characteristic of all four specimens of *Carmichaelia* which were examined, and as such deserves special notice. The region in which these plants grow is characterised by short, irregular rain-showers, which either run off quickly or are soon absorbed by the porous soil. It is probable that the presence of this shallow root system enables the plants to use to best advantage the irregular supply of water, while the deeper roots make use of moisture at deeper levels.

Carmichaelia Petriei is a leguminous plant, but it is peculiar that bacterial nodules were found to be extremely rare, and were of an unusual form, being larger and more branched than those found on common legumes such as peas or beans.

Hymenanthera dentata var. alpina T. Kirk.

This plant is by no means necessarily confined to sub-alpine regions. In certain places on the terraces, it occurs as rounded, compact, wind-moulded clumps about 1 foot in height (Fig. 22).

It is sparsely provided with leaves, and those which it has are quite small.

Only one specimen was excavated, on June 1. It was rather a small one, about 1 foot across and about 6 inches in height. It is typical of all the plants of this species in this locality that the crown occupies a bowl-shaped depression in the ground.

The root-system was characterised by a main taproot which measured 15 cms. in diameter at its origin and descended vertically—except for undulations and compressions—to a depth of 5 feet 6 inches, where it divided into two almost equal branches, which both pursued a horizontal course (Fig. 15). These were each followed for a distance of 4 feet, tapering extremely slowly, and were still 2 mm. in diameter when further excavation was abandoned. Judging from the degree of tapering which they showed, they must certainly have continued for at least another four feet.

The taproot gave rise to a number of horizontal laterals which attained a maximum lateral extension of 3 feet 6 inches, and ended in well developed rootlets, branched to the third and fourth order. The laterals in the uppermost foot showed a tendency to turn upwards and to approach closer to the surface. The soil for a depth of 10 inches from the surface was fine and brown, and was quite damp from recent rains. The surface root development was probably correlated with the presence of surface moisture at intermittent periods.

Comparatively few fine rootlets were borne upon the taproot itself, these being much more common on the horizontal laterals. The roots are light yellow in colour, and rather tough in texture.

As far as could be ascertained by actual visual and tactile examination, the distribution of soil moisture on the day of examination was as follows:—

Upper 10 inches	damp brown soil.
Next 4 inches	fine damp gravel.
Next 2ft 10in	fine dry gravel.
Below this	fine damp gravel.

Thus the surface moisture due to winter rains extended to a depth of 1ft 2in, followed by a dry stratum to a depth of 4 feet. At this depth the gravel again became damp, presumably on account of the capillary rise from the actual water-table.

The plant thus exhibits a well defined surface absorbing system, as well as a deeper absorbing system collecting from the capillary fringe. No doubt the existence of laterals at intermediate levels indicates that winter rains may at times penetrate to these depths. It is probable also that the roots can absorb moisture from soil which to outward appearance seems dry.

Lepidium sisymbrioides Hook.

This cruciferous plant is not at all common in the Cromwell district. In fact, its occurrence is rather sporadic, and specimens had to be searched for carefully. The above-ground part of the plant is very small, the average diameter being about 5 inches, and the radical leaves lie horizontally, close to the ground.

The root-system, however, is totally out of proportion to the size of the above-ground part. Two specimens were examined, on June 4 and 5. A prominent taproot is the main feature, about 8 mm. in diameter at its origin just below the multicipital crown, and in the two plants excavated, it penetrated to a depth of over 6 feet. (Fig. 16). The taproot was extensively bent and kinked in avoiding large stones on its way downwards. In the specimen figured, it tapered very gradually and at a depth of 6 feet 2 inches, when further excavation was rendered dangerous by caving shingle, it was still ·5 mm. in diameter. There were no laterals of any size, those that were given off being very thin and sparsely branched to the second order. The taproot was light yellowish brown in colour, and rather brittle.

To a depth of 5 feet the shingle was dry. At this depth, however, it became damp to the touch. The cortex of the root is thick in proportion to the stele, and it is probable that the plant's method of tiding over drought periods is to draw upon the moisture stored in the wide cortex.

Geranium sessiliflorum Cav.

This species is a very common member of the turf community, especially on the gravel terraces. The leaves lie close to the ground, their petioles springing directly from the multicipital crown of the taproot. One specimen was excavated entirely, but five others were examined to a depth of one foot. The taproot of the plant excavated entirely (Fig. 17) was about 15 mm. in diameter at its origin, and after descending vertically for a distance of 10 inches it divided into two almost equal branches, one of which continued downwards without major branches to a depth of 5 feet. The other branch divided at the 2-feet level, and the two branches so formed also continued downwards to a depth of 5 feet. From the taproot in its upper foot, a number of almost horizontal laterals were produced which branched in the upper soil to the second order. This production of surface laterals was found to be a constant feature in the five other plants examined. From the main divisions of the taproot comparatively few small laterals were produced, their number increasing, however, as the fifth foot was reached.

The taproot has a papery bark which is almost black, and which readily peels off, showing the reddish, woody, central tissues.

Chenopodium glaucum Linn.

Parts of the river banks, especially along the base of the Dunstan Range, are characterised by the presence of a salty efflorescence, which appears as white patches upon the surface. These patches are almost invariably colonised by *Chenopodium glaucum*, often in company with *Atriplex Buchanani*. *C. glaucum* is a summer annual, with fleshy, succulent, and prostrate leaves. The three root-systems shown in Figure 18 are those of three plants excavated on April 17. They are drawn to one-half natural size. It will be seen that a taproot is the dominant feature, which divides sooner or later into major branches.

The minor branches are thin and poorly developed. In two of the specimens figured, the taproot carries in its upper region small bunches of rudimentary rootlets, but in the third these are absent, being replaced by longer single rootlets. The taproot in all was about 4 mm. in diameter at its origin, did not penetrate more than 12 inches, and was white and soft in texture.

In comparison with the above-ground parts, which are thick, fleshy, and fairly widely spreading (up to 18 inches long), the root system is very poorly developed. The fine saline soil in which the plant habitually lives is retentive of moisture, and that which is absorbed by the roots is stored efficiently in the leaves.

Both *Chenopodium glaucum* and *Atriplex Buchanani* are halophytes occurring not uncommonly in sandy places near the sea, and the occurrence of a saline soil in the inland Cromwell district provides a suitable habitat for these plants.

Erodium cicutarium L'Herit.

This species, an introduced one, forms such an important constituent of the plant covering that it becomes dominant in the terrace community in the winter months. It is worthy of notice that Cannon (1911, p. 34) mentions it as becoming very widely spread in the deserts of Arizona. It is a true winter annual. Ten specimens were examined on June 1. The dominant feature of the root-system is a white fleshy taproot, which descends to an average depth of about 15 inches, tapering rapidly, and occasionally forking. The uppermost two inches of the taproot is generally provided with numerous short laterals, which arise in groups. Below this region are present a varying number of larger laterals (5 to 10) about 2 to 5 mm. in diameter at their origin, which may extend outwards and downwards for about a foot. These laterals carry smaller branches which are not extensively branched. (Fig. 19). Cannon (loc. cit. p. 24) mentions that a feature of the root-system of this plant is the poor development of laterals, but this character was not in evidence in the case of the plants examined in the present investigation.

THE FACTORS OF THE HABITAT.

I.—Climatic Factors:

Unfortunately, no meteorological station is situated at Cromwell, so that records of rainfall, temperature, wind, etc., are not available for the actual locality under consideration. But the area forms part of a more widely spread region which can be considered to have a very similar climate. A certain amount of data are available from Clyde and Earnscleugh, some 12 miles to the south-west of Cromwell, and from Ophir, in the valley of the Manuherikia River, a tributary of the Clutha. The general climatic conditions of these places are similar and can be taken as almost identical with those of Cromwell. The actual extent of the district which is considered in this paper is shown in Figures 1 and 20.

Light.—No exact instrumental data are available, but it is clear that the isolation to which the district is subjected is generally considerable. In summer, bright sunny days follow one another with regular monotony. The sky is generally free of clouds and the heat is often intense. During winter and spring, however, though sunny days are common, dense mists may hang over the valleys and tops of the ranges, completely obscuring the sun sometimes for days at a time. In the hot season, the light is made more intense on sandy bare areas by the reflection which occurs from them.

Rainfall.—The limiting factor of the environment is certainly the moisture available in the soil. The mean monthly and annual precipitation for Clyde is given in Table I, while similar data for Earnscleugh is given in Table II.

TABLE I.

Months.	Precipitation.	No. of Rain Days.	Months.	Precipitation.	No. of Rain Days.
Jan.	1·82	7·2	Aug.	·82	5·8
Feb.	1·04	5·0	Sept.	1·03	6·2
Mar.	1·48	6·3	Oct.	1·62	7·9
April	1·45	5·9	Nov.	1·32	6·8
May	1·05	6·0	Dec.	1·80	7·7
June	·95	5·4			
July	·91	4·9	Annual	15·29	75·1

Table I.—Mean monthly and annual precipitation and mean monthly and annual number of rain days at Clyde. (These figures supplied by Govt. Meteorologist).

TABLE II.

Months.	Precipitation.		Months.	Precipitation.
Jan.	1·74		Aug.	1·22
Feb.	1·10		Sept.	·83
Mar.	1·47		Oct.	1·70
April	1·62		Nov.	·99
May	1·36		Dec.	1·42
June	·89			
July	·85		Annual	15·19

Table II.—Mean monthly and annual precipitation at Earnscleugh over a period of seven years (1920-1926).

It will be seen from these figures that the monthly precipitation is low, and apparently more or less evenly distributed over the whole year. But consideration of these figures alone would give an entirely misleading conception of the amount of moisture in the soil at different times of the year. Considering the Clyde data, it is precisely in those months which show the lowest rainfall, viz., May to September, that the soil is wettest. The reason for this is to be found in the wide difference between the amounts of evaporation in winter and summer. During winter and spring, i.e., from about May to the end of October, the soil is generally quite damp to a depth of several feet, and it seems remarkable to an observer at this period that the plant covering is so sparse on the soil which appears eminently suited to carry a much more abundant vegetation.

The penetrating power of the moisture is considerably lessened by other factors. On the steep Dunstan slopes, the surface is baked hard, and in places is free of soil altogether. Much of the rain which falls comes in short, sharp, and heavy downpours, which runs off extremely rapidly. The effect of these downpours is to convert dry watercourses into torrents which scour out the soil, exposing the underlying rock. After a storm, a few hours of the hot summer sun causes the ground to take on its previous parched appearance.

On the flat terraces, however, there is little or no run-off. But the underlying formation is a lightly compacted gravel into which moisture sinks very rapidly. One of the difficulties with which farmers must contend is the serious loss of water which takes place from the water-races dug in the porous ground.

Another characteristic of the rainfall is that the same months of different years often show considerable variation in the amount of precipitation. Table III gives the monthly rainfall at Earnscleugh for the period 1921-1927. A glance at the table will show that October, generally the wettest month of the year, was in 1922 easily the driest. Although January (generally the hottest month) has an average of 1·57 inches, yet in 1928 it had only ·39 inches. Study of the data of Table III will show further variations of a similar nature.

TABLE III.

Month.	1921	1922	1923	1924	1925	1926	1927	1928	Monthly Averages.
Jan. ..	.83	2.17	2.92	2.98	.45	1.72	1.12	.39	1.57
Feb. ..	.65	.67	.76	.85	1.09	2.76	.93	1.48	1.15
Mar. ..	1.03	1.55	1.07	.64	2.70	.27	3.08	1.04	1.42
April ..	.83	1.72	1.48	3.05	.83	1.12	1.30	2.79	1.64
May ..	.84	.81	1.89	.62	.31	2.48	.62	.58	1.02
June ..	1.61	.39	1.57	1.01	.37	.68	.50	.40	.82
July ..	2.21	.96	.21	.95	.97	.14	.56	1.60	.95
Aug. ..	.53	.78	.57	.18	2.33	.82	.34	—	.79
Sept. ..	.96	.52	.11	1.11	.78	1.06	1.28	—	.83
Oct. ..	2.08	.15	.82	2.68	2.51	2.47	1.23	—	1.71
Nov. ..	.42	1.62	.58	1.13	.99	1.30	.90	—	.99
Dec. ..	1.76	2.05	1.48	.95	1.52	1.74	.46	—	1.42
Yearly Totals ..	13.75	13.39	13.46	16.15	14.85	16.56	12.32	—	

TABLE III.—Monthly and yearly rainfall (in inches) at Earnscleugh, 1921-1928.

The average number of days upon which rain falls during the year at Clyde is 75, a figure which gives an indication of the preponderance of dry days.

On the area considered in this study, only very occasional falls of snow are recorded. These are at most very light, and never lie on the ground more than a few days. On the ranges, however, which reach an altitude of more than 5000 feet, snow lies continuously above the 3000-foot level during the winter and spring months. This region is not considered here.

Humidity.—Information on this point is available from general observation only. Collection of exact observations would have required constant presence in the locality. It is apparent, however,

that the air humidity in summer is generally very low. The prevailing westerly winds have already deposited their moisture upon the mountains to the west, and by the time they blow over Central Otago they are warm and dry. During the winter and spring, however, owing to the prevalent mists, evaporation is slight and air humidity must frequently be high.

As a factor correlated with the study of root-systems, data bearing upon the soil water-content at different times and different depths would be important. This also requires constant presence upon the scene, and ideally, a laboratory on the spot. The only information that can be given on this point is that gained by visual examination while excavating the root-systems. As Weaver points out (1919, p. 24), root variations are probably due to a number of factors, among which water content of the soil and its penetrability probably stand first in importance.

Temperature.—New Zealand is commonly said to enjoy an insular climate, and for the most part this is the case. But in Central Otago, the widest region of the South Island, there is found an approach to continental range of temperature. The Cromwell district does not experience the lower temperatures of some other parts of Otago during the winter, but nevertheless the temperature occasionally reaches 15° Fahr. On the other hand, in summer, shade temperatures of over 100° Fahr. are not uncommon.

Table IV gives the mean monthly maximum and minimum temperatures at Earnscleugh over a period of four years, 1921 to 1924, inclusive. Additional data are not available for the extraction of a more accurate mean.

TABLE IV.

Month.	Max.	Min.	Month.	Max.	Min.
Jan. ..	97	37	July ..	52	20
Feb. ..	92	33	Aug. ..	64	22
Mar. ..	89	31	Sept. ..	77	25
April ..	75	26	Oct. ..	81	28
May ..	64	22	Nov. ..	90	31
June ..	55	21	Dec. ..	93	33

Table IV.—Mean monthly maximum and minimum temperatures in degrees Fahr. at Earnscleugh from 1921 to 1924.

It will be noted from these figures that even in the summer months (November to February) while the maximum temperature is high, the minimum temperatures recorded at night are often low, so that the vegetation is subjected to considerable diurnal and nocturnal extremes.

Going into the question more fully, and taking the year 1924 as an example, the records show that in January there occurred one day with a maximum temperature of 102° Fahr., while there were eighteen days over 80°. In February, there were twenty days over 80°, and in March, nine days over 80°. In the following November, there were fourteen days over 80°, and in December, eight days over 80°. These figures show that the high temperatures reached are the rule rather than the exception during the summer months.

Figures are available from Ophir giving the number of frosts recorded on the grass monthly. At this place a frost is regarded as any record below 30·4° Fahr. Table V gives these figures, and they are instructive in showing the duration and frequency of the low temperatures, especially during the winter months.

TABLE V.

Month:	Jan.	Feb.	Mar.	April.	May.	June.	July	Aug.	Sept.	Oct.	Nov.	Dec.
1926	3	2	9	12	24	30	29	29	19	16	12	8
1927	8	8	11	19	29	30	27	30	21	14	9	5

TABLE V.—No. of frosts recorded on the grass monthly at Ophir.

It will be seen that during the winter months frosts occur regularly—on almost every night. Moreover, the maximum temperature on many days of the winter months does not rise above 32° Fahr., and consequently the ground is frequently frozen hard for weeks at a time.

Wind.—During the hot summer especially, the area is subjected to violent winds from the north-west. These occur not infrequently and with great velocity, and are usually warm and dry. In conjunction with the intense insolation and low humidity, their effect is desiccating in the extreme, and evaporation must reach a maximum. These strong winds have been instrumental in moulding the sandy flat which characterises that part of the valley adjacent to Cromwell township. The sand is believed by some to have been brought down by the Clutha in the great flood of 1878, but Park (1908, p. 35) suggests a more likely source. He states that "this would doubtless account for a large proportion of the sand, but the terrace on which Cromwell is built contains a large amount of drift-sand mixed with the gravels, and a constant supply of this sand, derived from the terrace faces between Lowburn and Deadman's Point, is carried by the wind across Cromwell Flat." (Fig. 20).

As will be shown later, the distribution of the sand has had an important effect in modifying the vegetation of this flat.

Strong winds from the south-west also occur at all seasons, but these are generally moisture laden, and if they do not bring rain, they cause the higher levels to be shrouded by mists, especially in winter.

The effect of the wind in conjunction with the sand particles, is also seen in the disintegrating action which it has upon the dying *Raoulia* patches. These patches are a characteristic feature of the landscape, and lie close to the surface, where the sand blast action is greatest. At a certain age in the development of these circular patches, the central region dies, while the peripheral portion remains alive. The resistance of the central portion is lessened, and the constant bombardment of the sand particles has the effect of eroding the dead portion away (Fig. 5).

II.—Physiographic Factors:

The whole area is characterised by strong topographic relief. According to Park (1908, p. 15 et seq.), the valley had its origin as an area of subsidence involved in the greater "block mountain" system of Central Otago. Lacustrine and subsequent fluviatile deposition and erosion, combined with further faulting caused the valley to assume its present topography. It is flanked to the north-west by the Pisa Range, rising to 6300ft., and to the south-east by the Dunstan Range, rising to a maximum of 5320ft. At the lower end of the valley, to the south-west, lies the Carrick Range, about 5000ft. in height. The Clutha River, formed by the junction of the Upper Clutha and Kawarau Rivers, flows through the Dunstan Mountains in a narrow, deep gorge which turns off from the main valley about three miles from its south-west end. The floor of the valley is occupied by a system of terraces which clearly indicate the intermittent lowering of the base level of erosion.

The north face of the Dunstan Range is remarkable for its apparent barrenness. It is an excellent example of the influence of physiographic features in determining plant covering. The slopes are exceedingly steep, and characterised by immense outcrops of the mica-schist rock, of which the range is composed. The soil varies in thickness in different places. On the ridges and slopes it may be absent altogether, the surface being covered by angular stones weathered from the rocks above, owing to the daily extremes of temperature to which these rocks are exposed. On the other more level places, and especially at the bottom of the steep gullies, the soil may attain a depth of many feet. All gradations between these extremes may be present.

The flank of the range in question faces in a northerly direction and is thus exposed to the full glare of the sun. In summer, the heat of the surface of the ground is intense, often so hot that the stones cannot be touched with the bare hand. Buxton (1924) has made actual measurements of the heat attained on the actual surface of deserts, where it may be supposed that seeds must lie. He obtained temperatures of 60° C. (140° F.), where the shade temperature was 38° C. (100° F.). He points out that "reflected radiant heat is a factor with which desert fauna and flora have to reckon, especially in valleys." As shade temperatures of between 90° F. and 100° F. are common in summer in the Cromwell district, then it is reasonable to suppose that the surface of the ground would probably attain temperatures corresponding to those cited by Buxton—i.e., 140° F.

On account of the deep dissection of the main range by lateral valleys, certain slopes are much more exposed to the sun than others. The character of the plant covering in the shady slopes is consequently different from that of the sunny slopes. On the sunny slopes, the *Raoulia* patches are often the only occupants, with the addition of certain small annuals in winter and spring. On the shady slopes, the *Raoulia* patches are much closer together, and the annuals appear more abundantly. Comparison of the Dunstan side of the valley with the Pisa side, whose slope is towards the south, gives some idea

of the influence which the direction of the slope has had upon the plant covering. Both slopes in the past have been subjected to the same treatment as regards burning, stocking, and depredations of rabbits, but the Pisa side shows little of the depletion which so characterises the Dunstan side. The nature of the underlying rock is the same, the climatic factors are similar. Presumably, the direction of the slope has been chiefly instrumental in causing the difference in vegetation.

III.—Edaphic Factors:

The Dunstan and Pisa Ranges are composed of the same mica-schist rock which characterises a very large area of Central Otago. The soil derived from it is very fertile, as evidenced by the excellent crops which are obtained when irrigation is intelligently practised. The floor of the valley is largely occupied by fluviatile and lacustrine gravels. These are covered by a fertile soil of an average thickness of about a foot, which requires only sufficient irrigation to bring it into productivity. The soil covering in certain places is, however, very thin, and on the Cromwell Flat itself, is composed of drifting sand, which makes cultivation difficult.

The extreme permeability of the gravel beds causes the moisture that is precipitated to be quickly absorbed. The difficulty of getting water to the higher terraces, combined with the thirsty nature of the sub-soil has been instrumental in discouraging cultivation on these terraces. The soil itself is light in colour and texture, containing little humus, and consequently dries out very quickly.

On the lower terraces bordering the river, certain small areas of ground occur which are almost entirely bare of vegetation except for two species of plants, *Chenopodium glaucum* and *Atriplex buchanani.* These areas are composed of a very fine alkaline soil, derived as a concentrated decomposition product of the mica-schist rocks. On the surface a whitish crust forms in dry weather, the composition of which is given in Table VI.* The composition of the soil at a depth of six inches is given in Table VII.

TABLE VI.

Moisture	4.2	
Loss on ignition— (organic matter and water in combination)	4.4	
Soluble salts—		
Sodium chloride	3.7	22.0
Potassium chloride	(trace)	
Sulphates (mostly of Sodium)	16.1	
Sodium carbonate and other salts (by difference) ..	2.2	
Insoluble oxides	69.4	
	100.0	

Table VI.—Composition of surface crust of alkali patches.

*The author is indebted to Mr H. A. A. Aitken, M.Sc., Chem. Dept., Otago University, for the analyses given in Tables VI and VII.

TABLE VII.

Loss on ignition (moisture and organic matter)	5.15	
Soluble Salts—		
Sodium chloride	.27	.34
Other salts	.07	
Insoluble oxides	94.51	
	100.00	

TABLE VII.—Composition of soil of alkali patches at a depth of six inches.

It will be seen that the concentration of salts in the upper crust is excessive (22%), and far higher than that in the deeper soil (0·34%). A similar concentration of salts in the upper crust has been found in more extensive alkali soils in other countries. Nevertheless, even a concentration of 0·34% in the deeper soil, where it may be supposed that the plant has its absorbing system, is a higher concentration of salts than is found in ordinary soils. Only plants which can tolerate such an amount of salts in the soil, can thrive in such places.

On the Dunstan Range, below the 3000-foot level, the soil which remains on the surface, has probably derived the humus it now possesses from the decay of plants which formerly covered this part of the range. At the present time, almost the only plant which can be considered to contribute appreciably to the humus is *Raoulia lutescens*, but it cannot be said that the addition so made occurs in any quantity.

The Water Supply of the Soil.—On the slopes of the ranges, the water available for plant life depends almost entirely upon the scanty rainfall. The nature of the underlying metamorphic rock precludes any possibility of the existence of springs or water-table. Of course, fissures in the rock hold a certain amount of moisture, and it is upon this water that most of the very occasional perennials which occur can be reckoned to depend. As mentioned in the section on climate, the rain which falls comes in sudden, heavy showers, most of which runs off rapidly into the precipitous gullies, and subsequently into the Clutha River. The lack of plant covering must also lessen the amount of water retention. The surface of the soil is generally baked hard, so that there is no mulch to retard evaporation under a hot sun.

On the terraces, on the other hand, the presence of a water-table at varying distances from the surface allows deep-rooting plants to obtain water from its capillary fringe. Examination of the actual depth of the water-table in various places was too extensive a task to carry out, but certain observations were made while excavating root-systems. In one case especially, the response of the roots to the presence of the capillary fringe was found to be very striking (Fig. 11). The well-known water-holding capacity of fine sand has also been partly responsible in determining plant distribution. This point will be elaborated in a later section.

IV.—Biotic Factors:

The valley of the Upper Clutha, especially upon the Dunstan side, forms along with other regions of Central Otago, a very striking case of the influence of biotic factors in determining the character of the plant covering. The communities which now exist below the 3000-foot level (or thereabouts) can definitely be stated to owe their present nature largely to the destructive influence of fire, sheep, and rabbits, indirectly through the influence of man.

This conclusion can be arrived at not only by a critical study of existing vegetation, but is amply substantiated by the known history of the area as described by settlers of sixty and seventy years ago.

The lower slopes of the Dunstan Range before the occupation by the sheep farmer were covered by a community dominated by the tussock grass. Now, tussocks (*Poa caespitosa* and *Festuca Novae-Zelandiae*) grow only in shady or inaccessible places and alongside water-races. The ground is irregularly dotted with the intensely xerophytic cushions or patches of the close-growing *Raoulia lutescens*. A more complete description of the community is given later.

As Cockayne points out (1922, p. 328), the methods of sheep farming on other tussock grassland communities of New Zealand were, and still are, much the same as those used in the area under consideration. Burning, stocking, and rabbit infestation were as wholesale elsewhere as here. Yet only those parts of Central Otago which are subjected to such a semi-arid climate, the hottest and driest in New Zealand, have undergone depletion. That climatic and physiographic factors finally have the determining influence on the existing vegetation can be shown by the fact that, above 3000 feet, where the rainfall increases, although sheep and rabbits have access to these altitudes, depletion ceases. On sunny faces of gullies in the depleted zone, depletion is complete, while on the opposite shady faces, there are often many tussocks.

The harsh leaves of the tussocks do not afford very palatable feed for sheep, and so the early sheep farmers were in the habit of running indiscriminate fires through the grassland, to take advantage of the more succulent green leaves produced in spring. This burning was carried out year after year, the cumulative effect of which has proved disastrous.

In addition, the runholder stocked his land beyond its capacity, with little regard for the future. Finally, the coming of the rabbits fifty years ago added to the destruction. Their propensity for rapid reproduction and their voracious appetites are well known—" With an eminently favourable climate, abundant food, and a soil suitable for burrowing or rocks in plenty for their homes, these animals increased enormously, so that with them and the sheep, the country became greatly overstocked. Every plant at all palatable was eaten to the ground; the depleted area ascended higher and higher; those perennials alone could survive which either were not eaten at all or were furnished with far-extending underground stems, and

possessed the power of rapid growth after being cropped close. Then there were annual species, which possessed great and rapid powers of increase by means of seed, or, in the case of such plants as die yearly to the ground, by far creeping subterranean stems. It is the addition of the last three categories to the pasture—mostly foreign plants, with sorrel and wild geranium the most important as feed, whose advent in quantity has been made possible by the new ground—which has rendered the sheep runs still productive, bringing in far more good feed than the general aspect of the depleted areas would lead one to imagine." (Cockayne, 1922, p. 329).

The ubiquitous *Raoulia*, with its compacted habit, offered no food whatever to the rabbit or sheep, nor was it affected by burning. Foweraker (1917) has shown that its leaf surface, reduced to a minimum, protected by woolly hairs, gives it ample protection against excessive transpiration, and the water storage cells in its leaves gives it power to tide over drought periods. Its abundant winged fruits (it is a Composite) confers upon it efficient powers of dispersal. Its extensive, fibrous, and deep system of roots, occupying the greatest possible amount of soil, gives it power to withstand long periods of draught. All these characteristics combined enabled it to take possession rapidly of the ground made bare by the destruction of the tussock covering. It is dominant now on account of the inability of other plants to withstand the concerted influence of unfavourable factors, not because it occupies ground which might otherwise support tussock-grassland.

Cockayne (1922) has shown that fencing of small areas from stock and rabbits resulted in the rapid regeneration of the original plant covering only when the stumps or underground parts of these plants remained alive in the ground. Where all the plants were quite dead, regeneration took place very slowly by natural spread of seeds on wind-swept areas. But where seeds of both native and introduced plants were sown and raked in, these were able to germinate and establish themselves on the experimental areas.

At the present time, due to more intelligent farming, stocking is not quite so heavy, and rabbits have been greatly reduced in numbers. But, except on the Pisa south-facing side of the valley, no very appreciable difference in the amount of tussock can be observed.

While examining the locality, an interesting piece of evidence bearing upon the composition of the original vegetation was discovered. As previously mentioned, the range is characterised by great outcrops of rock, of very varying shapes and sizes. One such rock was discovered which possessed a more or less flat top. This flat top of the rock was obviously out of reach of sheep and rabbits, was also safe from fire, and could only be scaled with difficulty. On its summit were found eleven species of plants, excluding several mosses and lichens, growing in close association on a layer of soil. These were as follows:—

Poa Colensoi Hook (tussock growth form).
Poa caespitosa Forst (tussock growth form).
Pimelea aridula Cockayne (small shrub).

Pimelea Poppelwelli Petrie (small shrub).
Gaultheria antipoda Forst (small rigid shrub).
Cassinia fulvida Hook (shrub 2-6ft. high).
Senecio bellidioides Hook (herb).
Senecio Haastii Hook (herb).
Celmisia gracilenta Hook (herb).
Luzula campestris (var?) (herb).
Cheilanthes Sieberi Kunze (fern).

Now most of these species can be found growing as isolated specimens in crevices and more or less inaccessible parts of the rocks of the district, but their association here into a continuous covering on an area of about seven or eight square yards is a striking indication of the community which can and does exist when the influence of animals and fire is removed.

A feature of the lower parts of the gullies is the presence of old dried-up water-races, which were originally dug by gold miners twenty or thirty years ago. Even though some of these have been dry many years, they often show a growth of tussock along their beds and margins, illustrating the fact that when this plant is able to establish (on account of the temporarily increased water supply), it can live successfully on return of the natural conditions, provided there is a sufficient thickness of soil, and extraneous biotic factors are inoperative.

This evidence indicates that regeneration by natural processes, if possible, will necessarily occur only after a long period of time, and only if the biotic factors are entirely eliminated. The original plant covering was the result of perhaps hundreds of years of growth and decay. Man's influence reversed the process in a few years, and the return to the original state can occur only after the lapse of a very considerable period of time.

OBSERVATIONS UPON THE VEGETATION.

It is not intended to give here a complete account of the species which comprise the plant covering, but only to mention certain relevant observations.

The area can be divided into four main regions according to the plants which give each its distinct facies. These are as follows:—

(1) The Dunstan Lower Slopes.
(2) The Pisa Lower Slopes.
(3) The Terraces.
(4) The Cromwell Sandy Flat.

These divisions are based upon the broader features of the associations only. Various factors have modified the vegetation of certain localised places very considerably. For instance, along the banks of the Clutha River are immense heaps of "tailings" produced by the gold-dredges of twenty years ago. These have completely covered up much alluvial land, and formed large areas of barren shingle—heaps

of stones quite bare of vegetation in some places, and in others slowly being colonised by certain species. The succession on such places would be a study in itself. Again, there are a few places near the river which are subject to periodic flooding and which show a typical swamp association—as evidenced by consociations of *Typha augustifolia* and *Juncus spp.* Such localised places do not enter into this discussion.

I.—The Dunstan Lower Slopes:

An account of the severe factors of the habitat acting upon the association which covers this region has already been given.

The dominant species is *Raoulia lutescens* Beauv. The silvery green flat cushions of this plant (locally known as "scabweed") comprise the striking feature of the landscape. At all seasons of the year they retain the same appearance, seemingly unaffected by the changes in temperature or humidity. On steep and gentle slopes alike, their deep, fibrous roots afford ample anchorage and a sufficiency of water, while their reduced leaf-surface brings transpiration to a minimum. As mentioned above, the frequency with which the patches occur differs on sunny and shady slopes. Measurements of the diameter of a number of patches were taken during March, and these were checked again in August—six months later. It was found that during this period one patch had increased in average diameter by about one inch while others had increased by ¼-inch to ¾-inch. It is unfortunate that the observations could not have extended over a longer period—at least a year—so as to obtain more reliable results. Moreover, these measurements represent the growth during the slower growing period. However, supposing that one takes a conservative estimate of an average annual growth of one inch in diameter, one might well suppose, considering the numerous patches present, that in a very few years they would coalesce to form a continuous carpet. This is actually found in some south-facing slopes, but over the greater part it never occurs. The reason seems to be that after a certain maximum is reached, the patch begins to die away in the centre. Thus its resistance is lowered, and the wind aided by small stones and sand, soon erodes the dead portion away, blowing away also the humus which had collected beneath. Thus the original large patch becomes broken up sometimes into two, three, or four smaller patches, representing the peripheral living portions, and new ground is laid bare.

Considering the open exposed ground, that is, excluding such places as shady crevices between the large outcrops of rocks, and the rocks themselves—different seasonal aspects can be distinguished in the association.

Prevernal and Vernal Aspect.—As noted above, the *Raoulia* patches are present at all seasons, and maintain much the same appearance. But during the period between June and September, the ground between the patches becomes quite green with thousands of seedlings of such plants as *Poa Maniototo* Petrie, a small tufted

grass, *Agrostis alba* Linn. (introduced), *Stellaria gracilenta* Hook., a wiry herb, and *Mysosurus aristatus* Benth., a small herb with radical leaves.

Early Aestival Aspect.—From November to January the annuals which had germinated previously, develop and produce their seed. The abundant white starry capitula and winged fruits of *Raoulia lutescens* are produced during December and January.

Late Aestival and Autumnal Aspect.—From February to May the effect of the hot summer period shows itself, and the annuals are for the most part either dead or severely desiccated. *Poa Maniototo* persists as dead or almost dead tufts between the scabweed. Only the scabweed appears to be alive, and the soil between the patches is more or less bare. Small cushions of *Colobanthus brevisepalus* T. Kirk, one to two inches in diameter, appear to persist actually on the scabweed patches all the year round.

There are a number of shrubs which grow on the slopes. However, they are found only dotted here and there, and never occur in such numbers as to lend any distinct facies to the association. The commonest of these is *Hymenanthera dentata* var. alpina T. Kirk, an almost leafless, densely interlaced and low-growing shrub. *Olearia odorata* Petrie, *O. lineata* Cockayne, and also *Sophora tetraptera* Mill, are generally to be found in the more shady gullies, where they may attain the height of shrubby trees.

The moss and lichen flora is extensive, the abundance of bare, jagged rocks offering an excellent holdfast. The most abundant moss is *Grimmia trichophylla*, growing in small rounded cushions, its " leaves " covered with small silky hairs.

II.—The Pisa Lower Slopes:

It has been observed previously that these slopes face in a southerly direction, and that there is little of the depletion which so characterises the opposite side of the Clutha Valley. With the exception of but a few, all the plants growing on the Dunstan side are also present on the Pisa side of the valley, but they are present here with others, in far greater amount. Except on the barest tops of the ridges between the lateral gullies, *Raoulia* species are rare. The tussock grasses (*Poa caespitosa* and *Poa Colensoi*) are specially abundant, and in most places the silver tussock (*P. caespitosa*) forms a continuous covering, becoming the dominant species. It has already been stated that this difference in vegetation is considered to be in direct relation to physiographic features.

III.—The Terraces:

The terraces occupy the greater part of the floor of the Clutha Valley at this part of it (Fig. 20). They are composed of great thicknesses of fluviatile and lacustrine gravels which for the most part are covered by a layer of light-coloured soil of an average depth of about one foot. The gravels are absorbent and quickly take up the moisture which is precipitated.

The association, except where man's activities have completely changed it, shows definite seasonal aspects. During the prevernal and vernal periods the dominant species are *Erodium cicutarium* L'Herit, and *Rumex acetosella* Linn., both introduced plants. The latter is present almost the whole year round. Associated with these species is a very abundant lichen which has not been identified. This lichen is peculiar in being quite unattached, and in cartwheel tracks and slight depressions it may be scooped up in handfuls. No apothecia could be discovered upon it. Almost as frequent as the *Erodium* are dead stumps of the tiny *Poa Maniototo* Petrie. Patches of a species of *Polytrichum* are also common.

During the early aestival period, the continued hot weather causes the lichen to dry up and disappear. *Erodium cicutarium* becomes less dominant, and *Rumex acetosella* to a large degree persists, giving to the ground a reddish tint.

Over the greater part of the terraces, especially wherever the top soil becomes thinner, the patches of *Raoulia lutescens* and *R. australis* occur dotted here and there. In places where the top soil is very thin or even absent altogether, these plants may be the sole occupants, but for the most part they do not occur to nearly the same extent as on the lower slopes of the Dunstan Range.

In certain places *Geranium sessiliflorum* Cav. may become an important member of the turf. The character of the gravel is apparently very suitable for the development of its characteristic surface and deep sets of absorbing roots. Its comparative rarity on the Dunstan slopes may be explained on similar grounds—i.e., that a sufficiently great depth of soil is not present to allow of the development of the deeper roots of this type of root-system.

Hymenanthera dentata var. alpina occurs as compact low shrubs (Fig. 22).

Poa caespitosa is conspicuous by its absence. This would seem to be related to the character of its root-system. The species is distinctly perennial and requires a certain minimum of moisture in the surface soil all the year round, owing to its shallow root-habit. The absorbent nature of the sub-soil causes the top soil to dry out in summer very easily, and thus the moisture content is too low to allow this tussock to live, except in shady places, or where for any other reason the amount of surface moisture is maintained. It will be shown in considering the Cromwell sandy flat that other reasons do here permit the establishment of *Poa caespitosa*.

IV.—The Cromwell Sandy Flat:

It has been shown under the section on Climatic Factors that this area is for the most part covered with a layer of drifting sand derived from the sandy faces of the terraces near Deadman's Point. The area which is so covered can be seen by reference to the map (Fig. 20).

A combination of factors has here brought about the dominance of *Poa caespitosa*. The root-habit of this species is a shallow one,

and it is well known that fine sand retains moisture quite near the surface very efficiently. It is noteworthy that wherever the thickness of sand is sufficient to allow of the retention of surface moisture, then *Poa caespitosa* becomes dominant. Where sand is lacking on this flat, *Raoulia lutescens* is dominant. Gradations can be found where the two species are evenly mixed, owing to the depth of sand being just enough to allow the growth of a few plants of *Poa caespitosa* and not enough either to bury the scabweed or to permit the tussock to become dominant over it.

The sand which is derived from the terrace face is not evenly distributed over the flat. In one place especially, the wind causes the sand to be distributed in a narrow strip over the flat, extending for about a mile. The surface of the ground of this strip does not appear sandy, being covered with a thin layer of humus derived from the dead leaves of the tussock, and when the strip of tussock was first observed, the reason of its occurrence was not apparent. But when the character of the root-habit of *Poa caespitosa* was ascertained, and actual examination of the top soil of the strip was made, the cause of this peculiar distribution became evident. Figure 23 shows the abrupt ecotone between *Poa caespitosa* and *Raoulia lutescens* where this strip is situated. By digging it was found generally that wherever the depth of sand over the ground was more than 6 to 9 inches, then the tussock was able to become dominant over the scabweed.

Some areas of the flat where the wind has removed both soil and sand are completely bare of vegetation except for *Raoulia lutescens* (Fig. 5). Others approach the character of the terrace association, with *R. lutescens*, *Poa Maniototo Rumex acetosella*, and *Erodium cicutarium* the leading species.

Where the deposition of sand has been particularly heavy, drifting dunes have been formed. On such dunes *Ammophila arenaria* (marram grass) has been introduced, and Figure 24 shows it in association with *Poa caespitosa*.

THE LEAF ANATOMY OF SOME OF THE PLANTS.

With a view towards gaining a fuller insight into the relation between the plants and their environment, the leaf anatomy of some of the species whose root-systems have been described, was studied. It was considered sufficient for the purpose required to make transverse microtome sections of the leaves. Five species were thus examined. Of these, the leaves of *Poa caespitosa* and *Lepidium sisymbrioides*, as well as the cladode of *Carmichaelia Petriei*, are well equipped with those modifications generally accounted xerophytic. Thick cuticle and sunken stomata are common to all three, while in addition *Poa caespitosa* exhibits a strong inrolling of the leaf. *Hymenanthera dentata var. alpina* and *Geranium sessiliflorum* on the other hand, show no marked xerophytic adaptations in their leaf anatomy. A very full description of the autecology of *Raoulia lutescens* has been given by Foweraker (1917), and a figure of a transverse section of the leaf of *R. tenuicaulis*, which is similar to

R. lutescens, is supplied. The white tomentum and development of large-celled water storing tissue of this leaf can be interpreted as definite xerophytic adaptations.

It would seem, then, that not all the plants habitually thriving under semi-arid conditions display in the anatomy of their leaves devices for the reduction of transpiration.

CONCLUSIONS AND DISCUSSION.

In the foregoing, the root-habits of seven indigenous and one exotic species have been described. Although perhaps a greater number of examples would be a desideratum before drawing definite conclusions, yet those examined are the most characteristic of the dry area, and using some of the principles deduced by other investigators of root-systems, some conclusions can be formulated.

A classification of the root-systems of perennials based on physiological rather than systematic lines has been put forward by Cannon (1911, p. 87). He distinguishes three types, namely, the generalised type with taproot and laterals both well developed, and two specialised types, of which one has a prominent taproot and the other prominent laterals. He concludes that perennials with the generalised type of root-system have the widest local distribution, and those with a pronounced development of taproot have the most limited distribution. He also states that the specialised type of root-systems of either form are changed little with environment, but the generalised roots are often extremely variable, ranging from a pronounced taproot to a marked development of the laterals, dependent on the soil characters and water relations.

Just how far these conclusions can be applied to the root-systems of the plants of the semi-arid districts of New Zealand cannot be properly ascertained until more data are accumulated. It is difficult to fit such a root-system as is possessed by *Raoulia lutescens* into the classification Cannon suggests, unless it is deemed to be a generalised one. On the basis of this classification, however, *Carmichaelia Petriei, Hymenanthera dentata var. alpina, Geranium sessiliflorum,* and *Raoulia lutescens* would be generalised types, while *Lepidium sisymbrioides* would be a specialised type, with prominence of the taproot.

Certainly in the examples of *Carmichaelia Petriei* which were excavated, the development of the laterals, in so far as their lateral extension was concerned, varied greatly in different stations, thus illustrating its adaptability. (Compare Figs. 11, 12, and 14). But it also has a limited local distribution—possibly on account of the influence of other factors, viz., the lack of any special means of dispersal of its heavy seeds. *Hymenanthera dentata var. alpina, Geranium sessiliflorum, Poa caespitosa,* and *Raoulia lutescens* have all a wide local distribution, and may be found on all depths of soil, and must therefore be capable of extreme variability. The character of their root habit is in accordance with this conclusion. *Lepidium sisymbrioides,* with its prominent taproot, is limited in distribution,

and it can be fairly certainly asserted that it would not occur except in soils which would allow such penetration of the taproot. Throughout New Zealand, *Poa caespitosa* thrives under a variety of climatic conditions. But in the semi-arid district, its moisture requirement in the surface soil is just at the point of balance between an adequacy and a deficiency. Any factor which tends to bring the soil moisture in the uppermost two feet of soil above a certain minimum, will favour the dominance of the tussock. A knowledge of its root habit gives a clearer insight into its distribution.

The presence of plants having a system of roots absorbing from the capillary fringe indicates the possibility of using on the terraces crop plants which are known to have a similar habit, e.g., lucerne. The difficulty with regard to this is that the young plants would need to be supplied with water by irrigation for two or three years until the deeper roots had been established. This has been the experience in certain parts of the U.S.A. (Meinzer 1927, p. 89). It appears that provided the lucerne is tided over the critical period in the first few years of its life, then satisfactory crops are returned without further irrigation. However, the author adds that " on lands where natural subirrigation has proved feasible, the soil and subsoil down to the water-table is a dark grey clay loam or sandy loam and a black loam derived largely from decomposed peat. Attempts to extend cultivation of subirrigated lucerne to adjoining areas where the subsoil is gravelly have not proved successful, although the depths to the ground water in these areas are no greater than in the area where success has been attained."

It may be added, however, that the depths to ground water in the above mentioned region were from 9 to 15 feet. From the few observations made upon the soils of the Cromwell area, the depths of the capillary fringe at least, seems to be somewhat less than these figures, in one case 4 feet. This relative shallowness of the water-table might well discount the difficulty of the presence of a gravelly subsoil.

Three of the species examined were found to have distinct surface and deeper systems of absorbing roots, viz., *Carmichaelia Petriei*, *Geranium sessiliflorum*, and *Hymenanthera dentata var. alpina*. This character seems to be a distinct development in relation to the water supply of the soil.

The true definition of the term " xerophily " has been much discussed. (Delf, 1915). The older view was to class as xerophytes those plants with form and structure apparently adapted to reduce water loss by transpiration. But it has been proved that not all plants which grow in such places are so modified, and plants with thickened cuticle, sunken stomata, or succulent leaves are not exclusively characteristic of desert places. Two examples can be quoted from the present study, viz., *Hymenanthera dentata var. alpina* and *Geranium sessiliflorum*, neither of which has leaves highly modified to reduce transpiration.

It has also been shown that the idea that saline and moorland soils are "physiologically" dry is unfounded. Plants with succulent and sclerophyllous leaf structure have been found to transpire freely. A calculation of the total leaf surface of *Calluna* (the Northern heath) puts it ahead of many mesophytes in its proportion of transpiring surface, and an examination of the amount of transpiration of the plant as compared with its absorbing system, shows *Calluna* to be able to lose water like a mesophyte, because in its natural habitat plenty of water is practically always available.

Delf (1915), after examining the evidence, concludes that "xerophily cannot be adequately defined in terms of habitat, of anatomy, or of physiology alone. It is rather a natural conception involving the total reaction of the plant environment. In general, it may be said that xerophilous plants are those which with the help of certain structural modifications can continue to perform their vital functions when exposed to climatic conditions involving atmospheric or edaphic drought or both. Atmospheric drought causes production of cuticle and often of more or less sclerotic subepidermal tissue. Edaphic drought may be met in at least three ways:—

1. By the development of a deep root-system penetrating to a constant water supply in the subsoil.

2. By the production of a generalised root-system with tissues which can develop very high osmotic pressures, so that absorption is possible even in air-dry soil.

3. By a superficial root-system with capacity to form adventitious collecting rootlets rapidly after rainfall. When there is a regular rainy period, however short, the superficial root-system is usually accompanied by the development of much aqueous tissue for water storage.

In the light of the definition given above, it becomes evident that no single character should be selected as an unfailing criterion of xerophily. All the characters of the plant should be taken into account; but even when this is done, the final proof should come from actual experiment.

It has been shown previously that the Cromwell district is subjected to both atmospheric and edaphic drought. In *Raoulia lutescens* we have a plant which probably owes its widespread occurrence to a combination of the above characters, i.e., a deep, generalised, and superficial root-system, as well as the development of an aqueous storage tissue. No experiments upon the actual water loss of this plant have ever been carried out, but it is possible that the amount transpired may be greater than would be supposed.

With regard to the other perennials which have been discussed in this paper, there can be little doubt that the consideration of their root habit in conjunction with their above-ground parts, shows them to be true xerophytes.

SUMMARY.

1. This study was undertaken to determine the root habits of some of the plants of the Cromwell district, an area which can be considered fairly representative of the most arid region of New Zealand, with a view towards correlating the knowledge so gained with the character, distribution, and succession of the vegetation.

2. The investigation was carried out at intermittent intervals over a period of seven months, from February to September, 1928, during which time about 30 individual root-systems belonging to nine different species of plants were excavated.

3. The method of examination consisted in digging a trench alongside the plant, thus exposing a vertical face from which the roots could be dissected.

4. The roots of the dicotyledonous perennials were found to penetrate nowhere less than four feet, and in some cases more than six feet. The grass investigated (*Poa caespitosa*) penetrated to an average depth of three feet, with the bulk of its roots in the upper foot. The two annuals examined did not penetrate more than eighteen inches.

5. The dicotyledonous perennials showed a definite tendency to develop a deep and a surface system of absorbing roots. This can be interpreted as a response to the character of the environment.

6. The leaf anatomy of *Hymenanthera dentata var. alpina*, *Geranium sessiliflorum*, *Lepidium sisymbrioides*, *Raoulia lutescens* and *Poa caespitosa* are briefly described. Although some of these species may develop a very thick cuticle, others, notably the first two named, do not. The inference is that leaf anatomy alone is not a reliable criterion of xerophily.

7. The presence of plants having a system of roots absorbing moisture from the capillary fringe indicates the possibility of utilising on the terraces crop plants which have a similar habit.

8. The district can be divided into four main subdivisions, according to the communities which characterise them, viz.:

(a) The Dunstan Lower Slopes.

(b) The Pisa Lower Slopes.

(c) The Terraces.

(d) The Cromwell Sandy Flat.

The climatic factors are similar on all these divisions. Edaphic, physiographic, and biotic factors have been instrumental in causing the differences between them.

9. A study of root habit in conjunction with a knowledge of the above-ground parts of plants gives a fuller understanding of the problems of competition, succession, and distribution.

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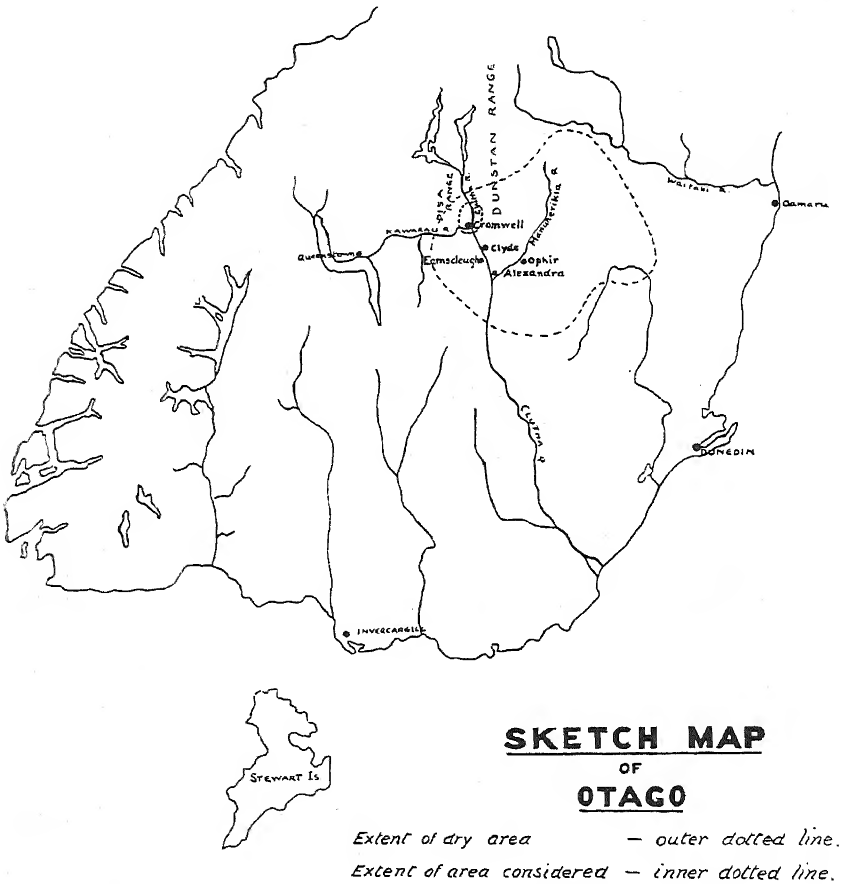

FIG. 1.—Sketch Map of Otago.

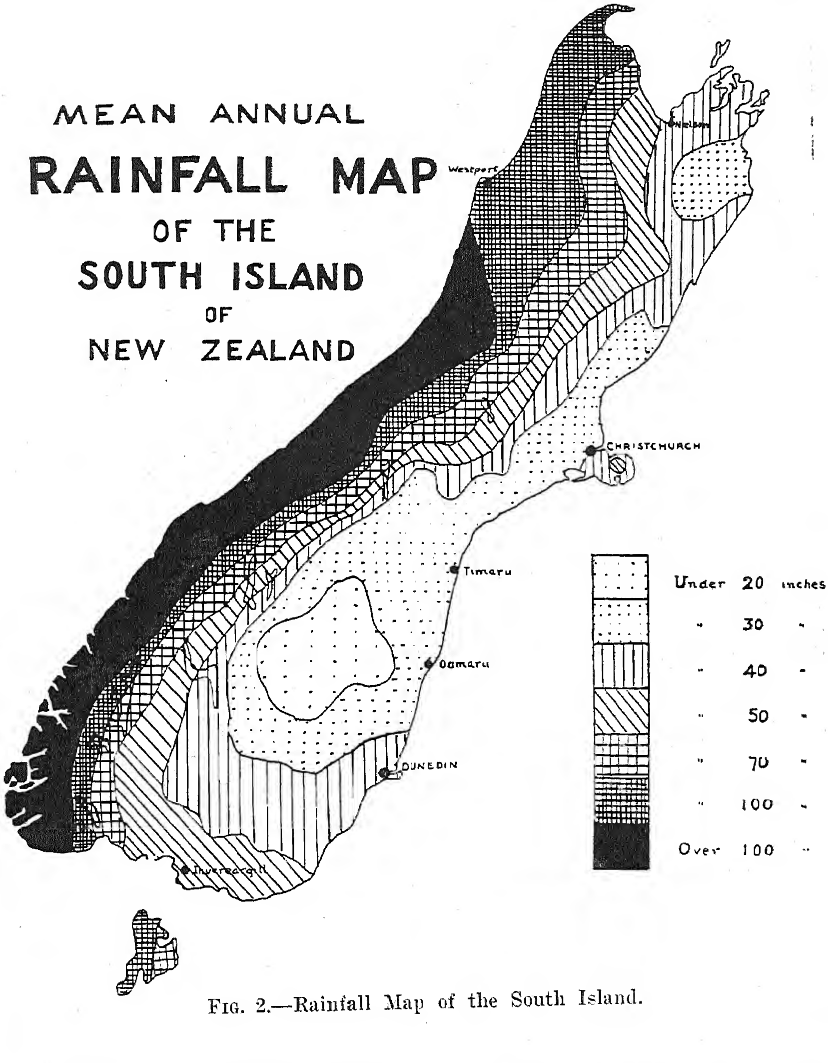

Fig. 2.—Rainfall Map of the South Island.

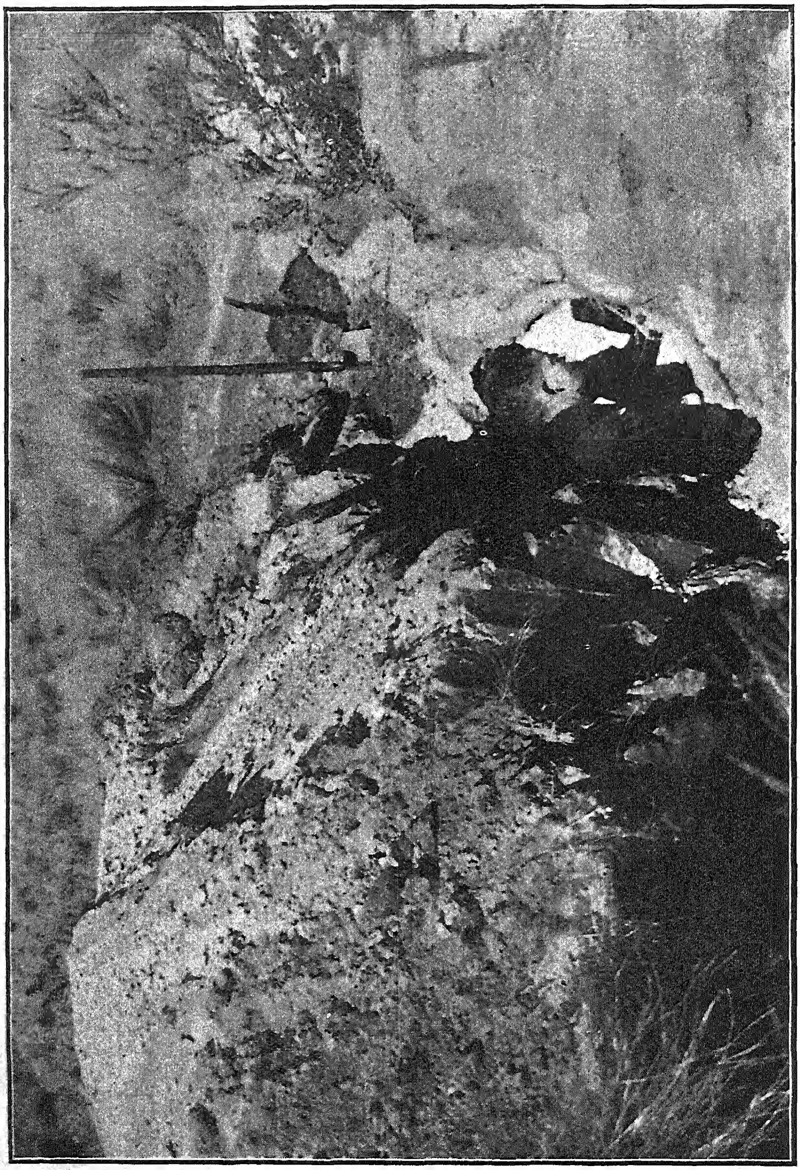

Fig. 3.—Part of a trench excavated in examining the root-system of *Carmichaelia Petriei.*

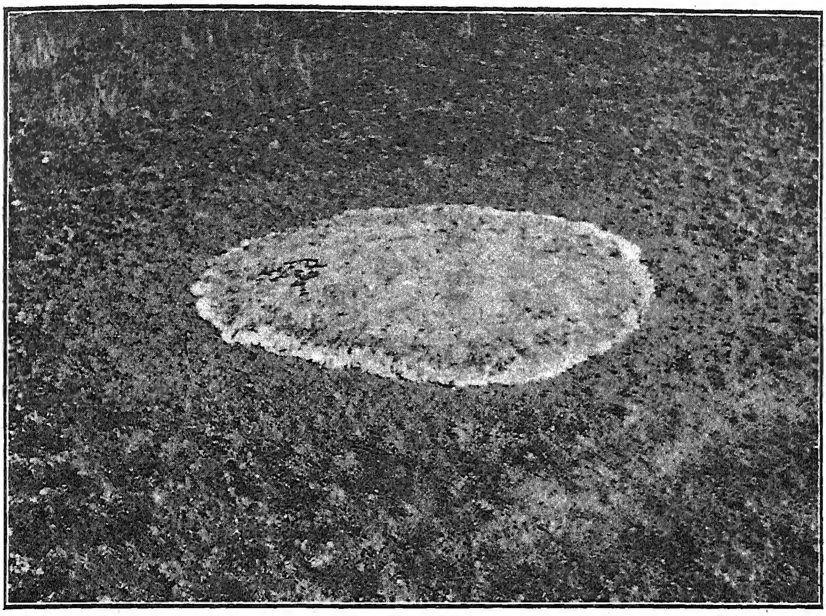

FIG. 4.—A single specimen of *Raoulia lutescens* growing on the terraces. Note the bare appearance of the ground immediately around the plant, owing to the root competition set up between the roots of the scabweed and those of the annuals around it.

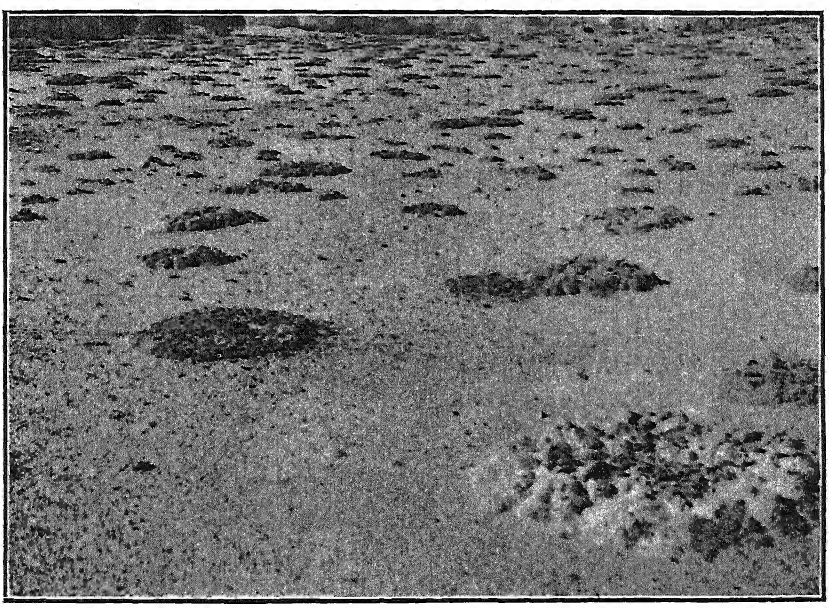

FIG. 5.—*Raoulia lutescens* in sole possession of a wind-swept area. Bare gravel between the cushions. Note the patches beginning to die in the centre.

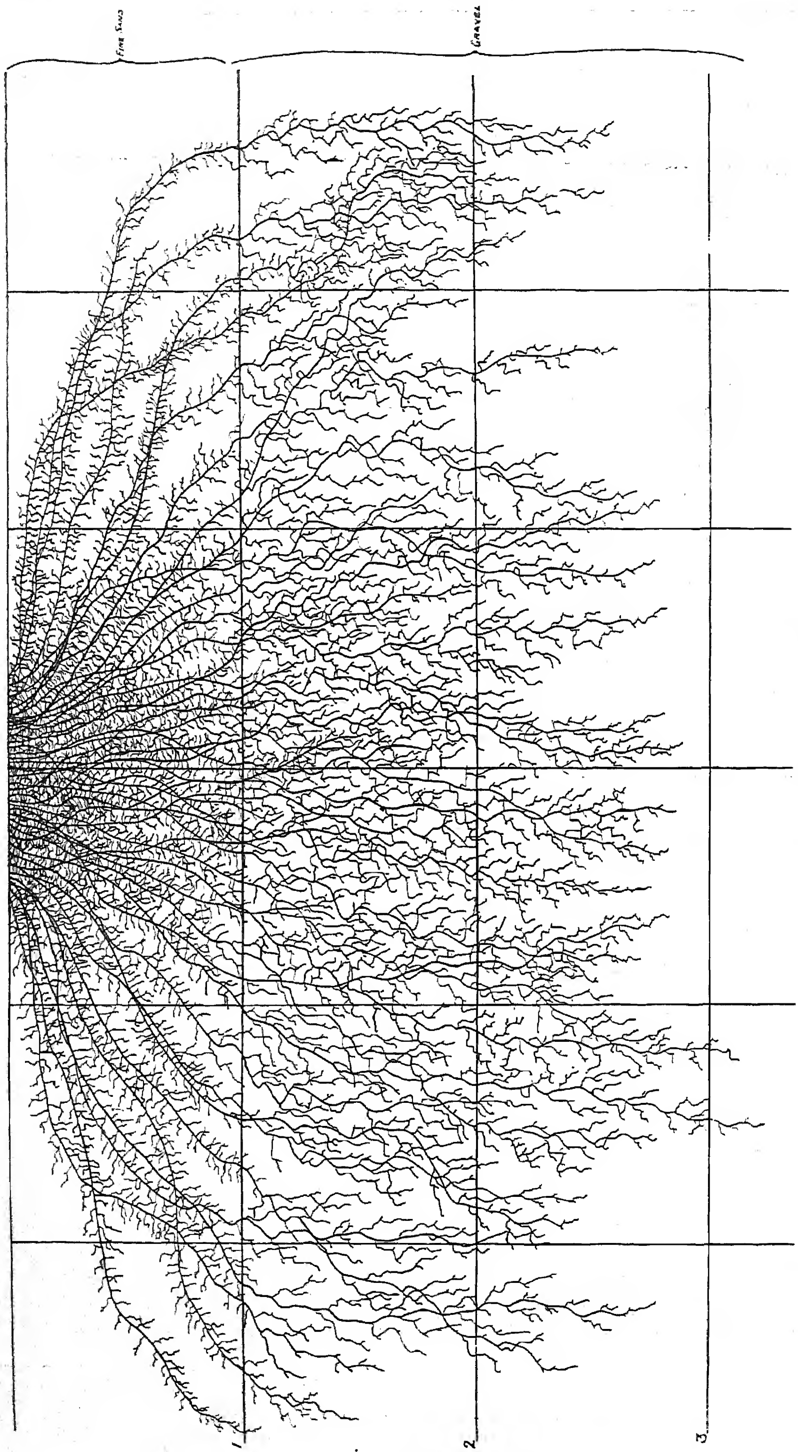

Fig. 6.—*Poa caespitosa.*

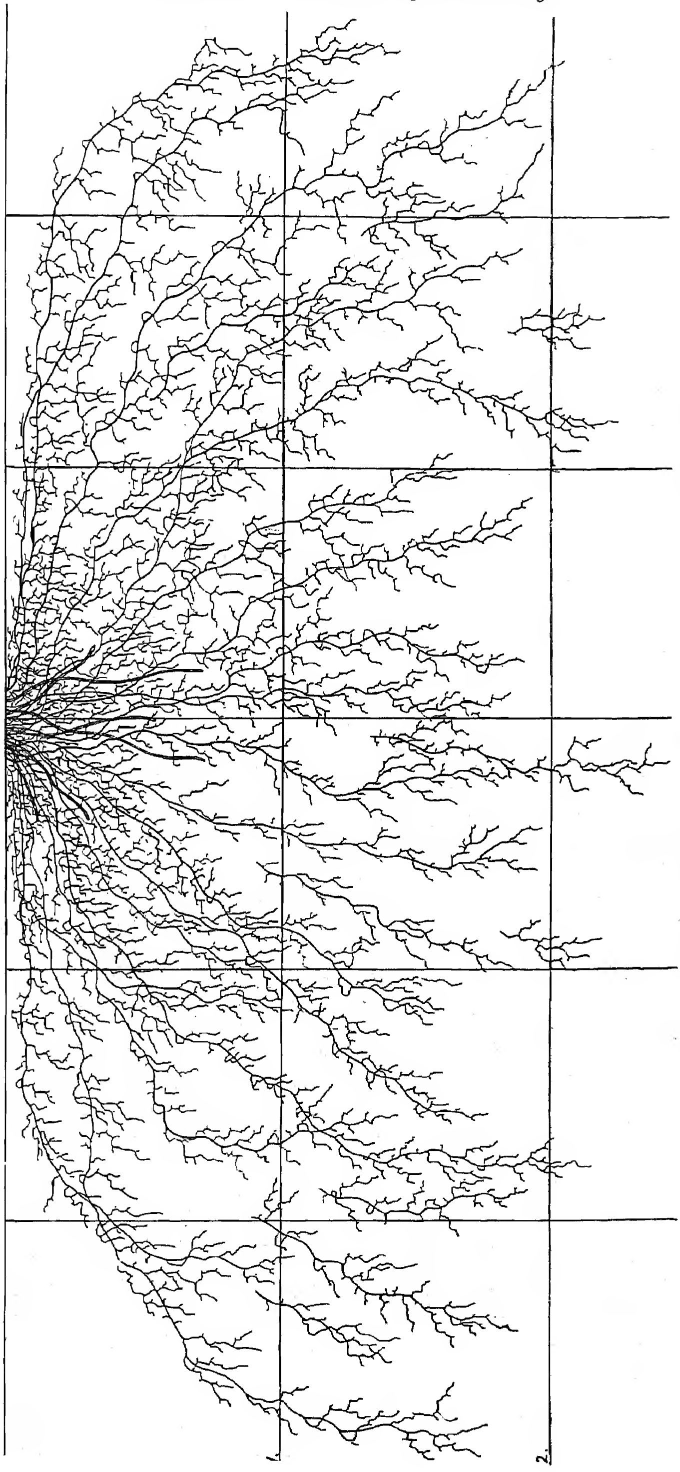

Fig. 7.—*Poa caespitosa.* Note new roots emerging from base of culm.

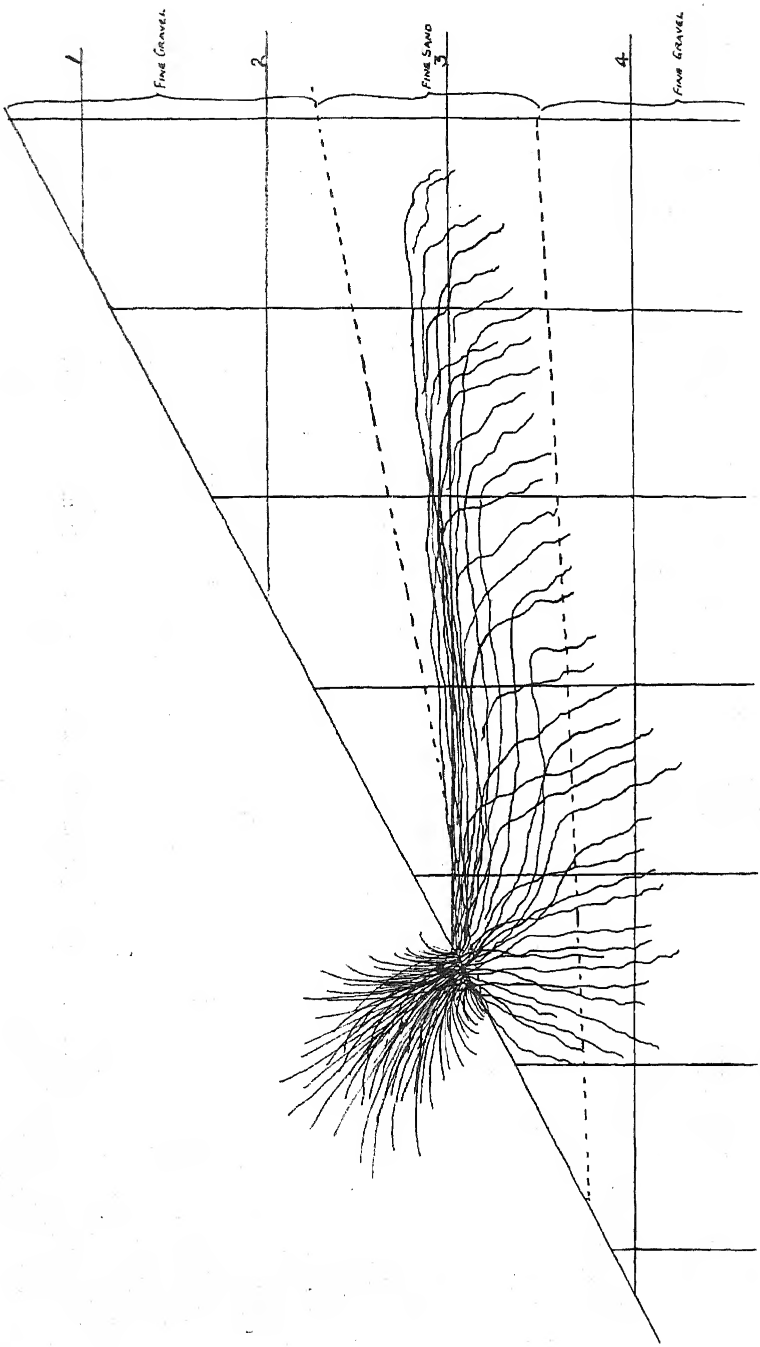

FIG. 8.—*Poa caespitosa* growing on a steep gravel slide. (The short laterals are omitted from the drawing).

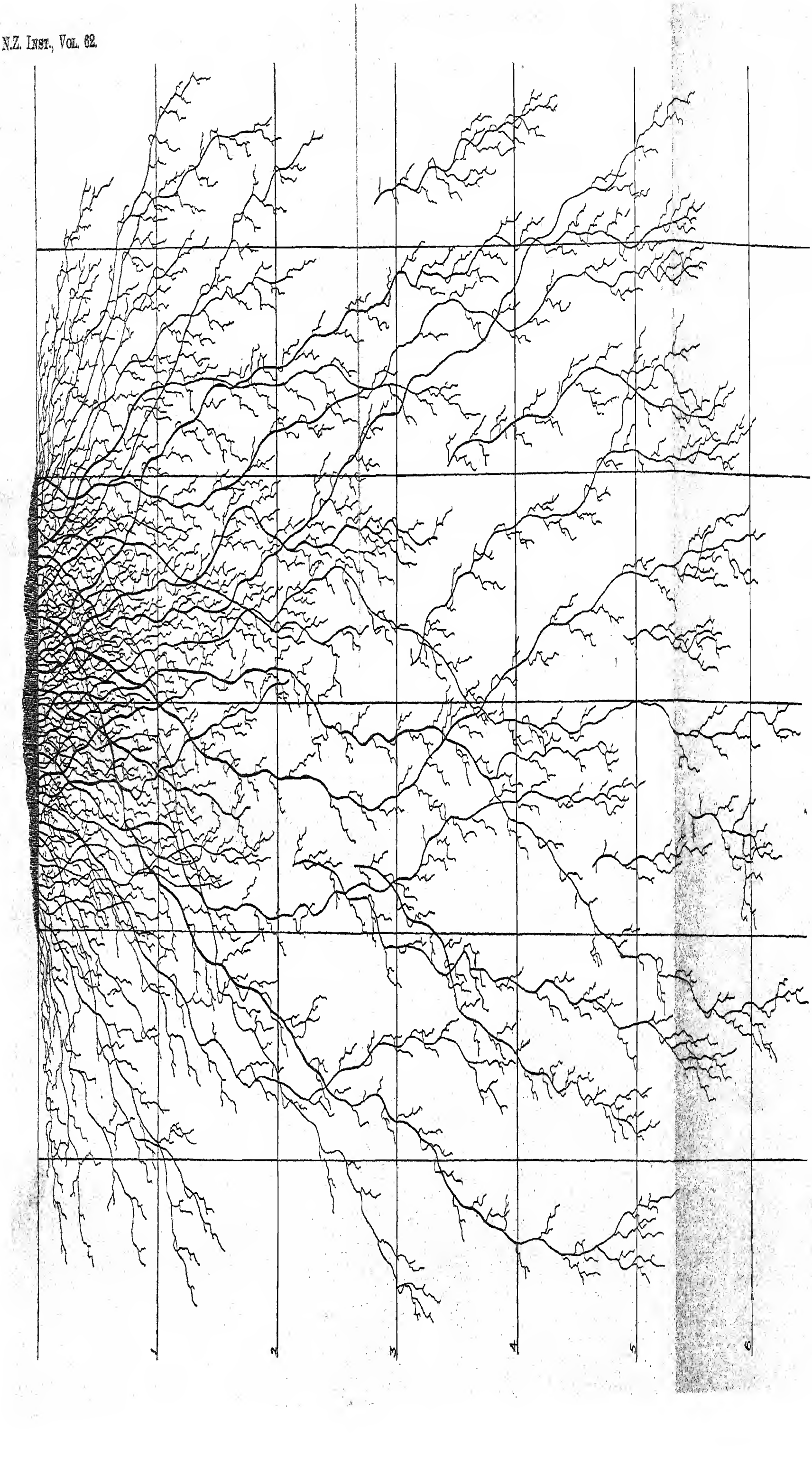

Fig. 9.—*Raoulia lutescens.*

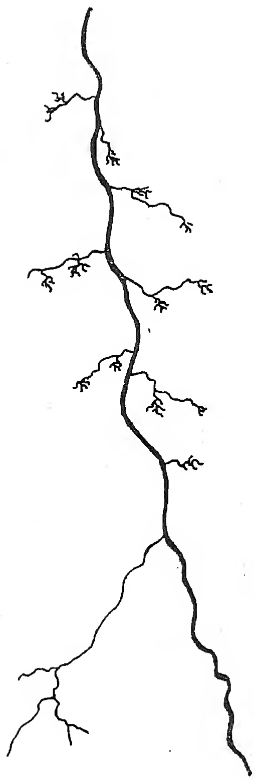

Fig. 10.—*Raoulia lutescens.* A portion of a root in the upper soil, showing the development of rudimentary roots after rains.

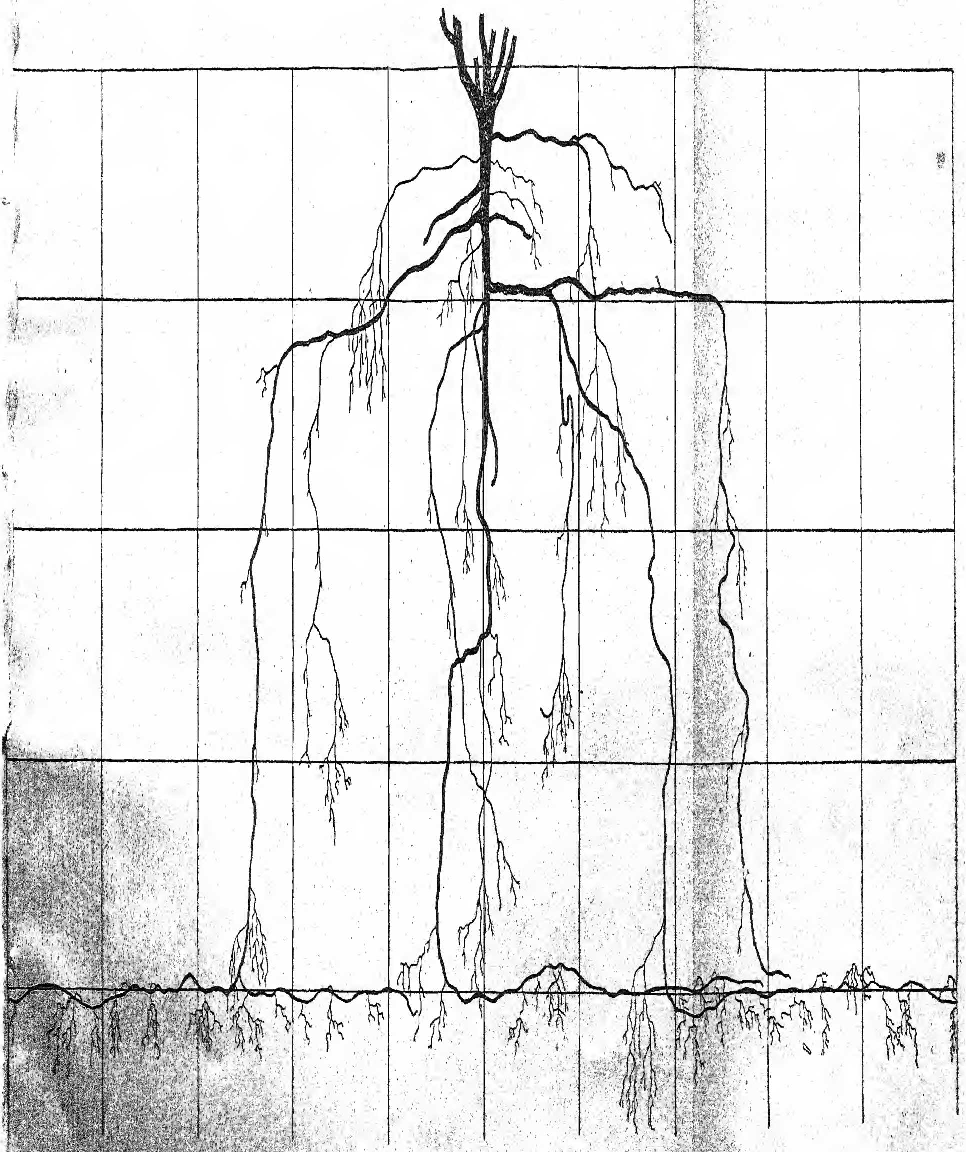

Fig. 11.—*Carmichaelia Petriei.*

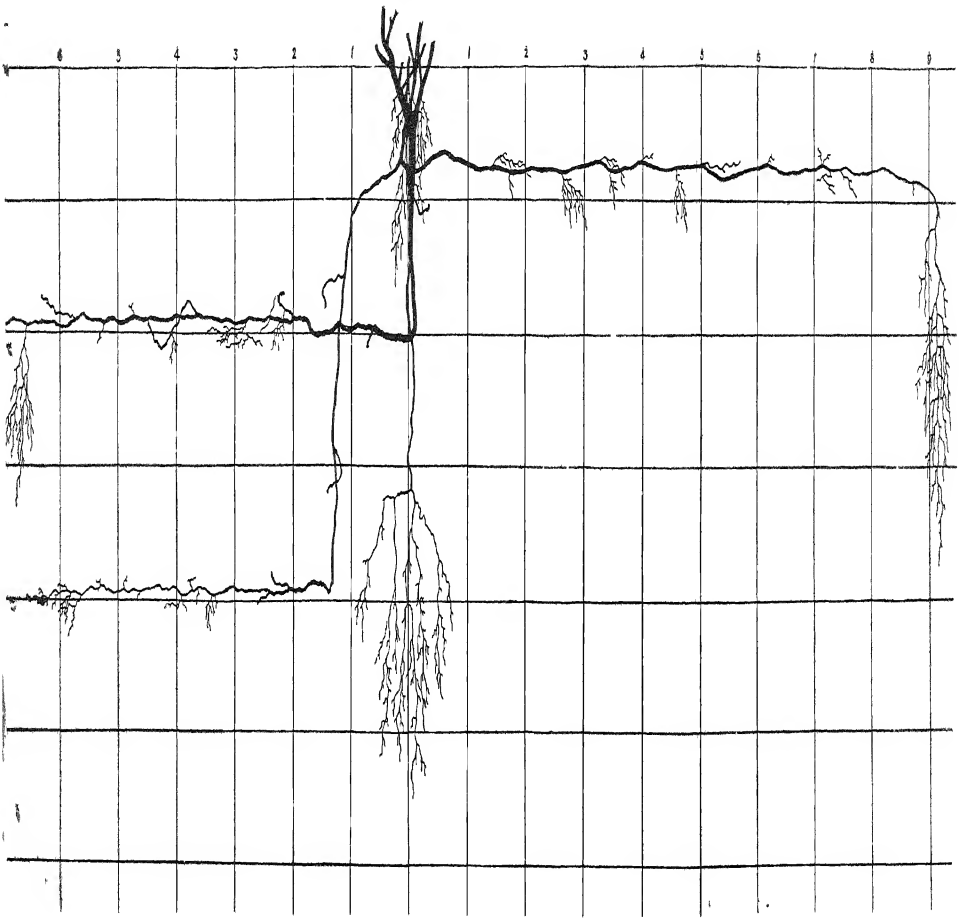

Fig. 12.—*Carmichaelia Petriei*, showing wide lateral extent of roots.

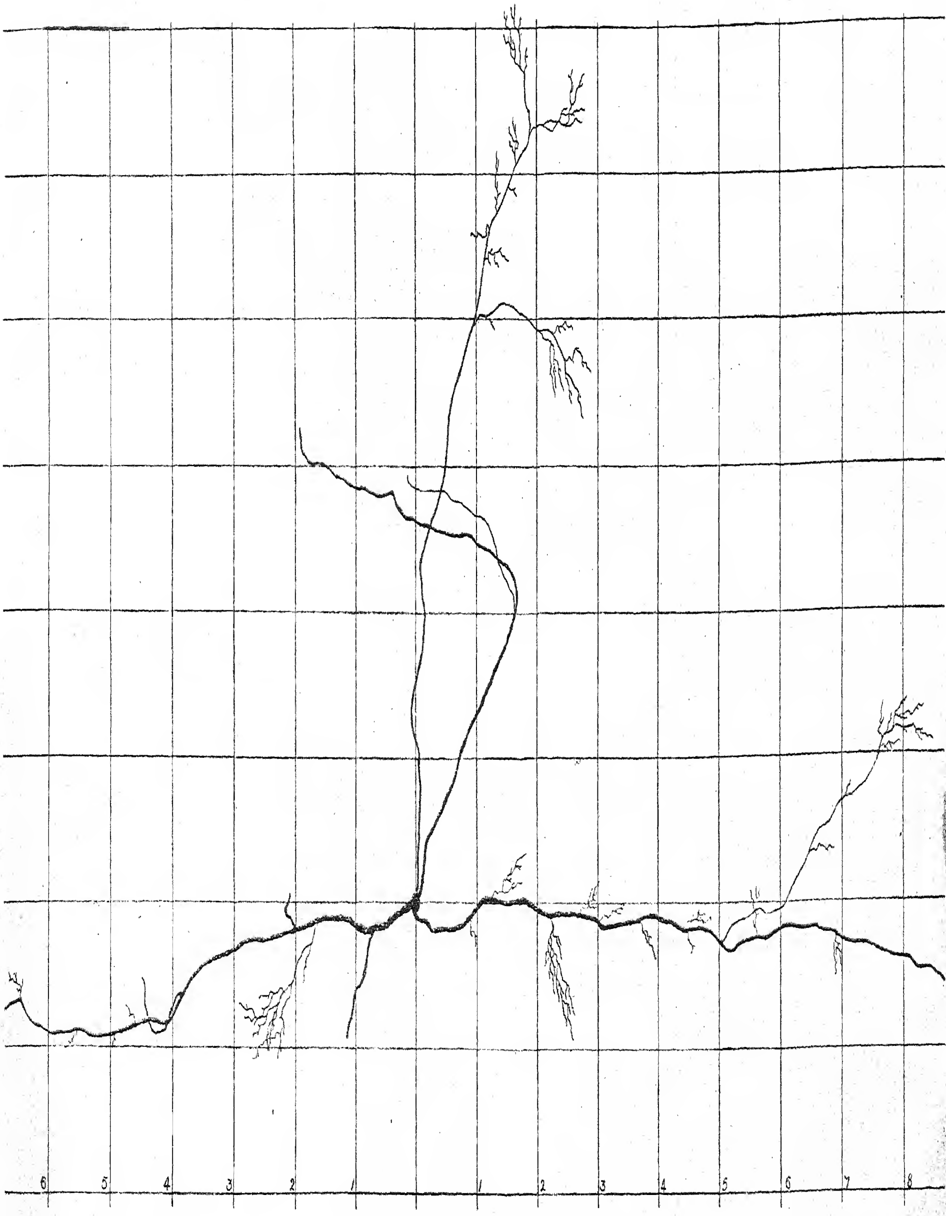

Fig. 13.—Surface view of the roots of the specimen of *Carmichaelia Petriei* shown in Fig. 12.

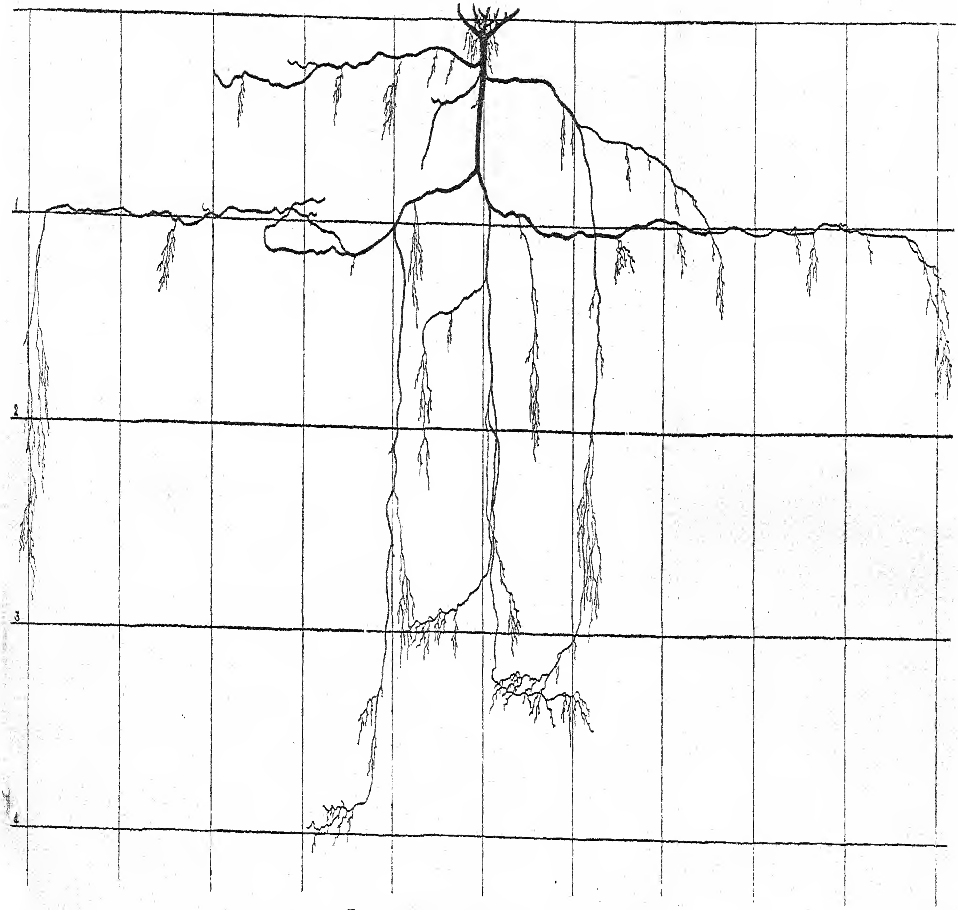

Fig. 14.—*Carmichaelia Petriei*, from edge of terrace.

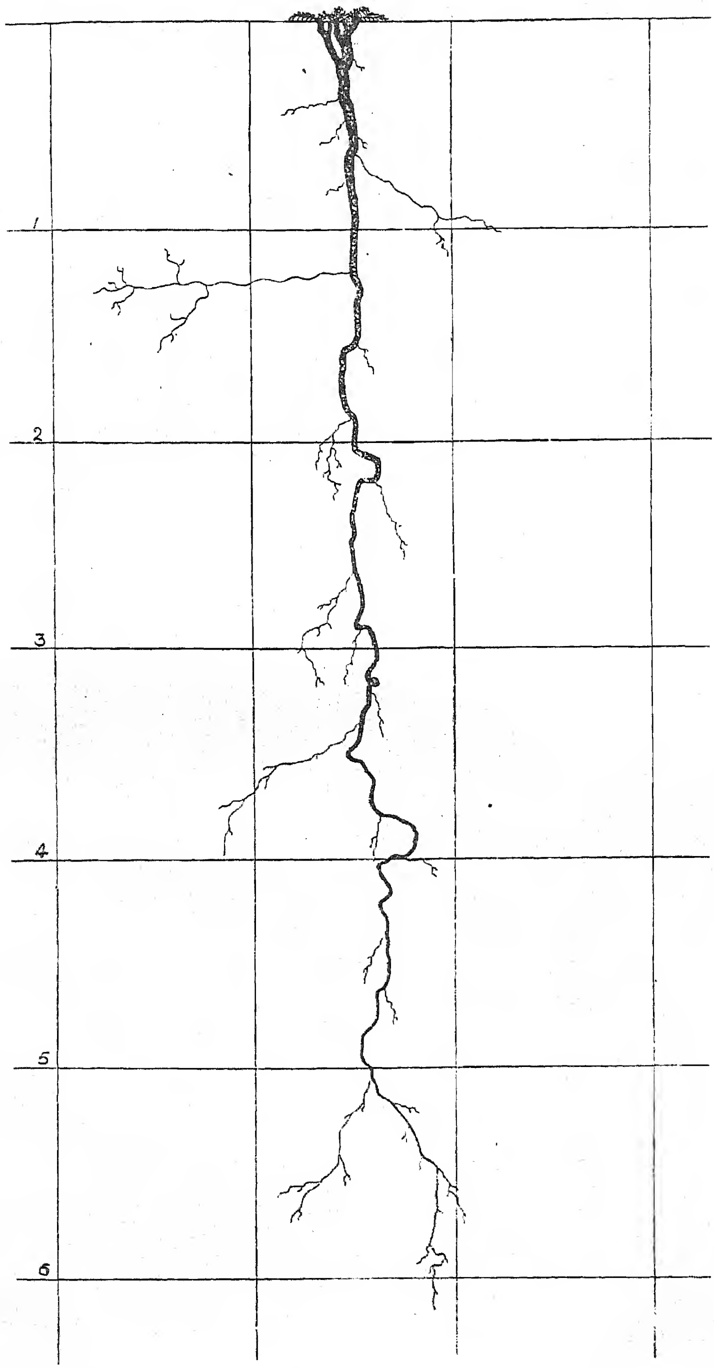

Fig. 16.—*Lepidium sisymbrioides.*

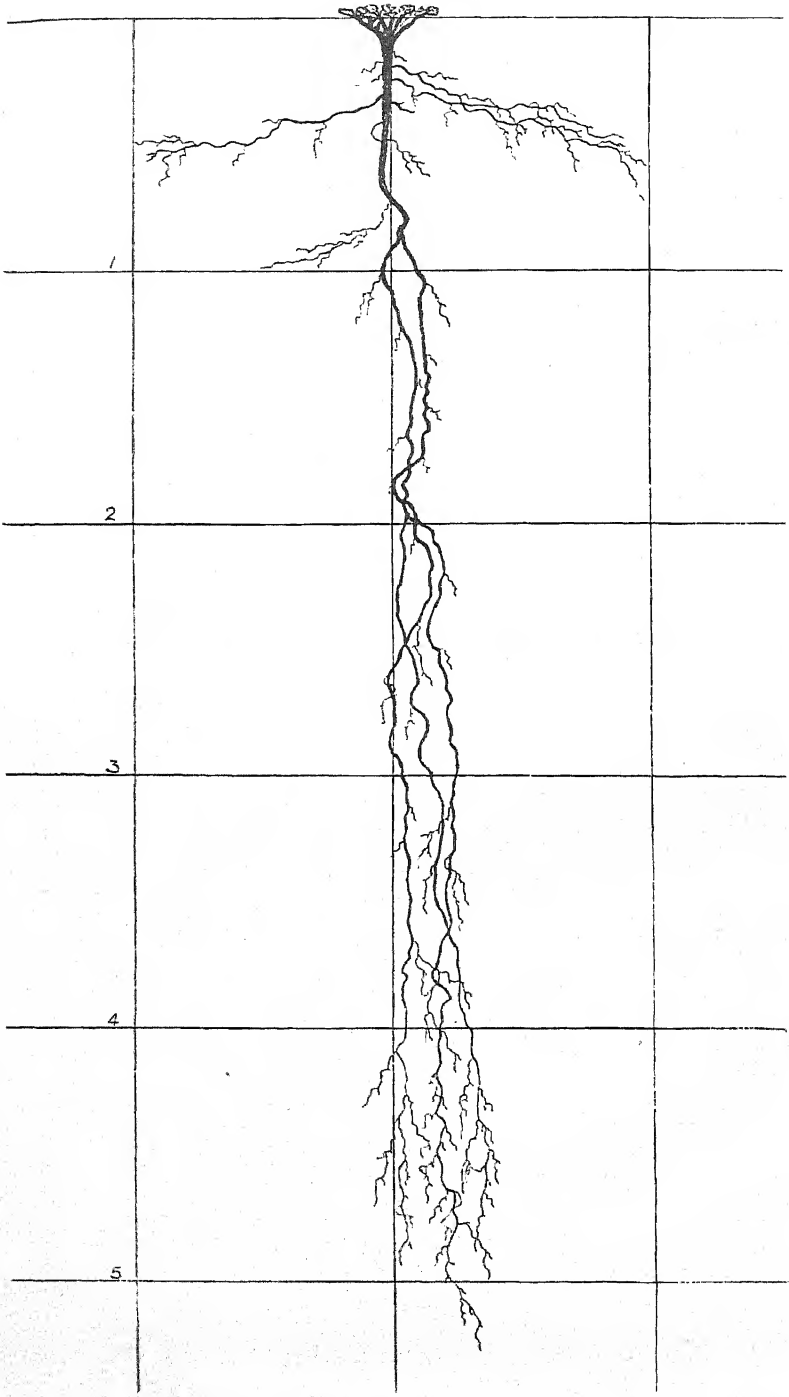

Fig. 17.—*Geranium sessiliflorum.*

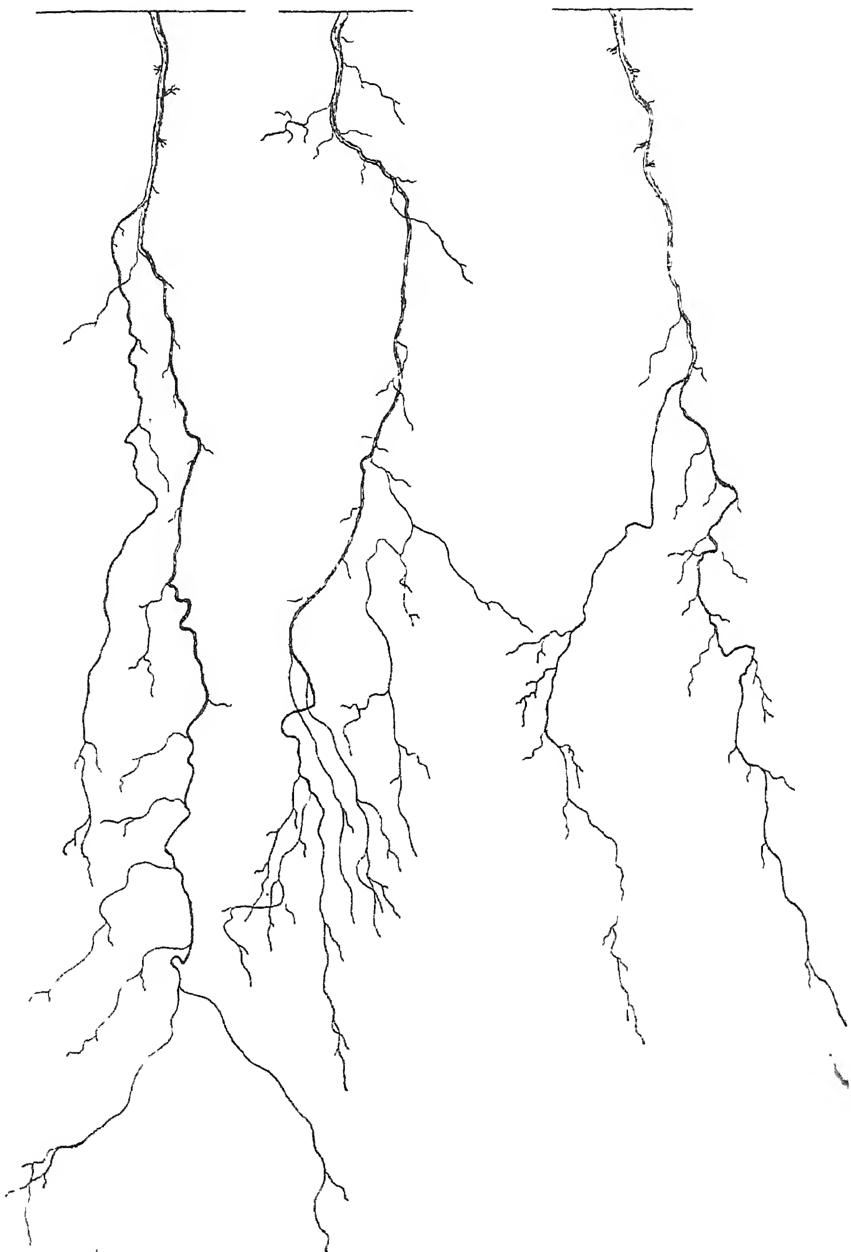

FIG. 18.—*Chenopodium glaucum*. The root-systems of three different specimens, half natural size.

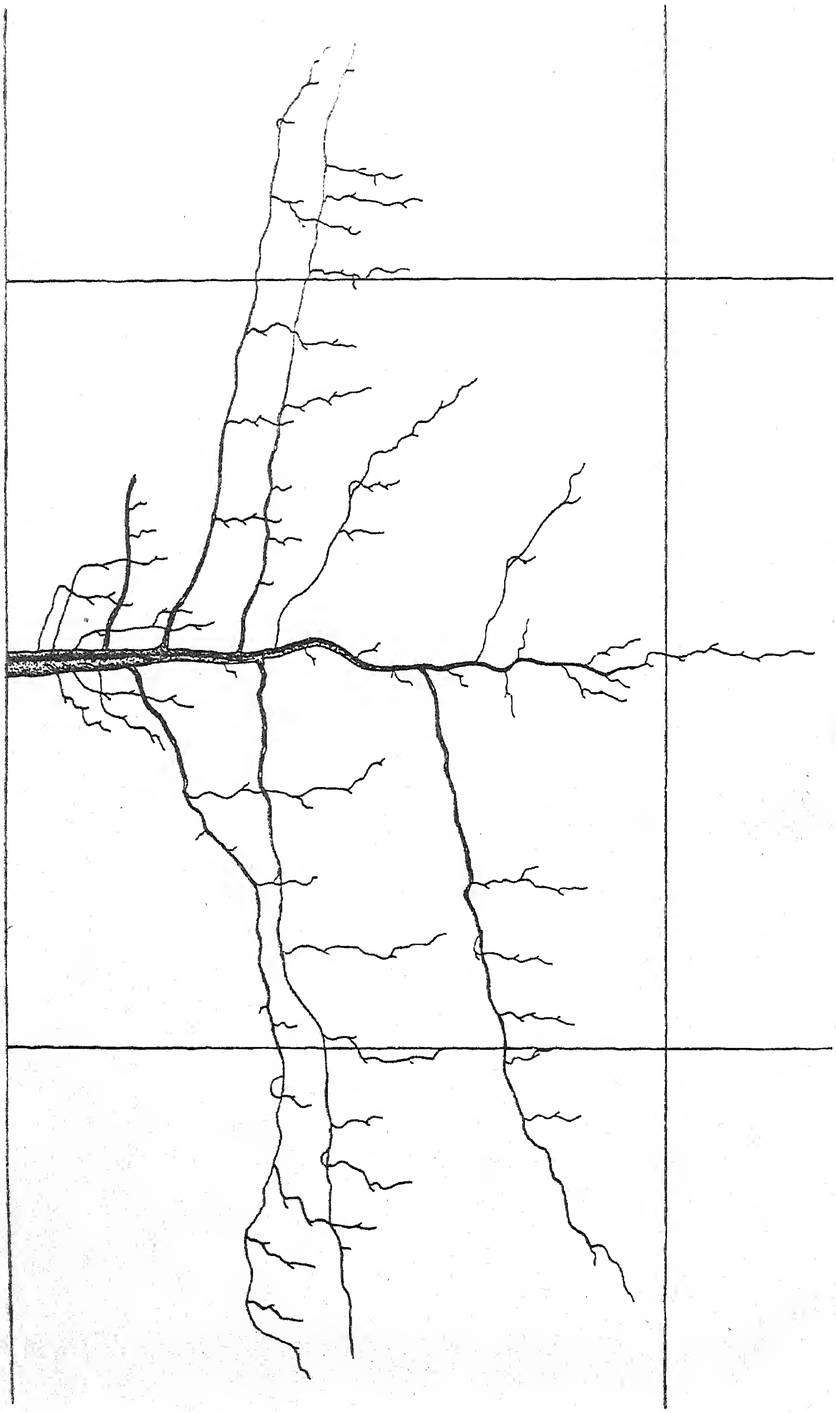

Fig. 19.—*Erodium cicutarium.*

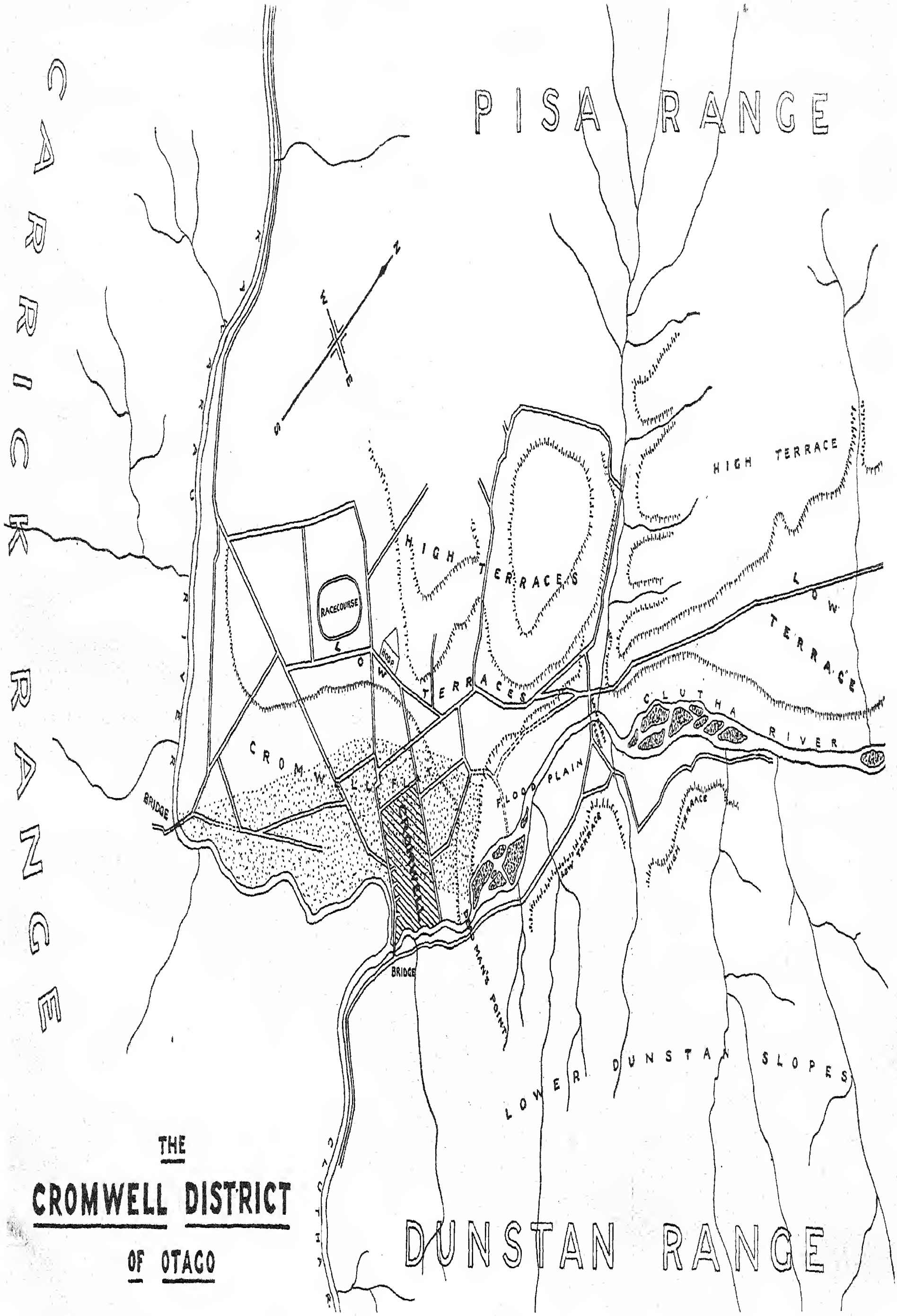

Fig. 20.—Map of the Cromwell district of Otago, showing points referred to in the text. [Adapted from Park, 1908.]

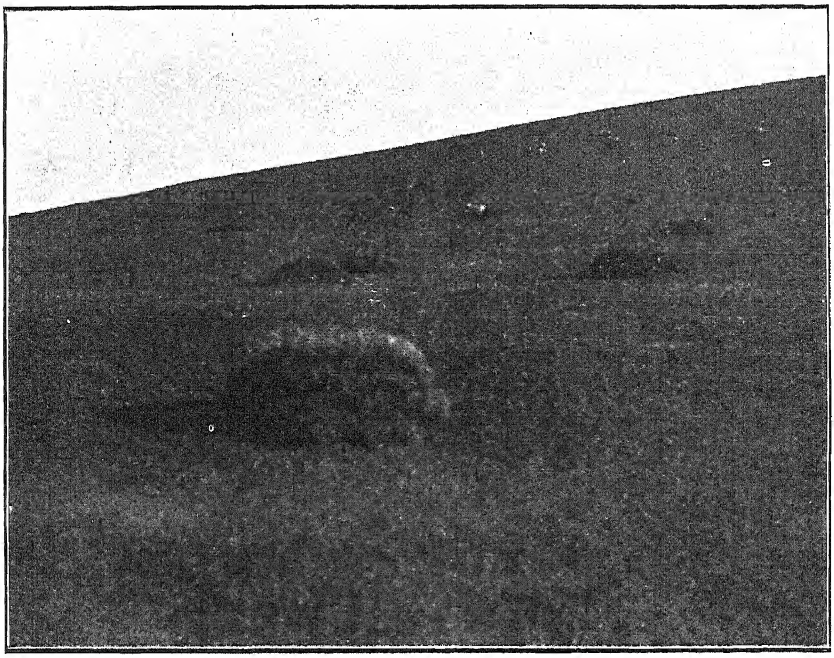

Fig. 22.—Habit of *Hymenanthera dentata var. alpina.*

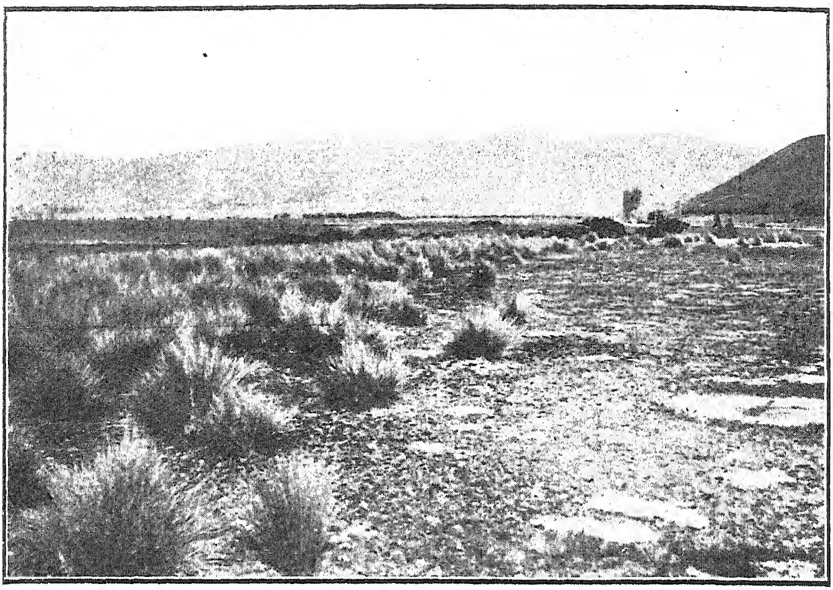

Fig. 23.—The margin of a strip of *Poa caespitosa* on the Cromwell Flat. *P. caespitosa* dominant to the left, *Raoulia lutescens* dominant to the right.

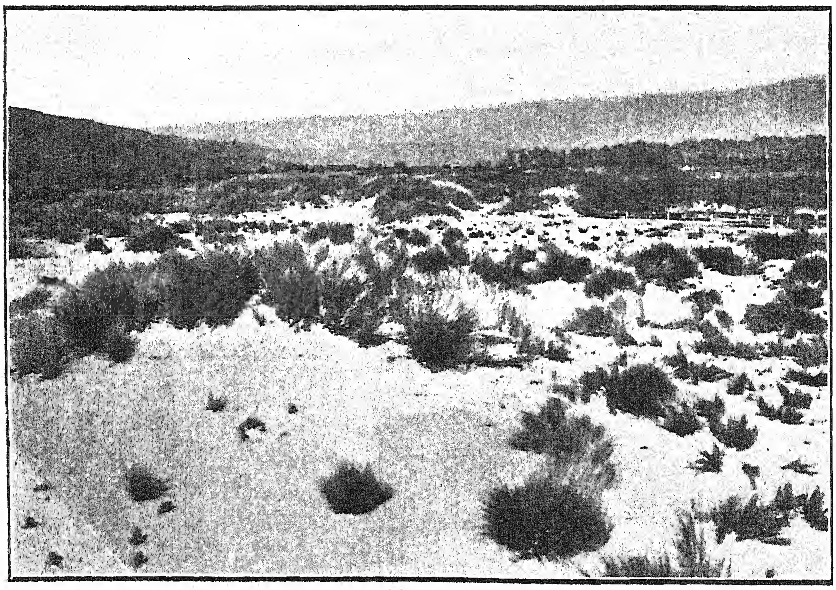

Fig. 24.—Typical sand dune formation on Cromwell Flat. *Ammophila arenaria* and *Poa caespitosa* acting as sand-binders. Belts of Salix in the background.

APPENDIX.

THE HUTTON MEMORIAL MEDAL AND RESEARCH FUND.

Regulations under which the Hutton Memorial Medal shall be awarded and the Research Fund administered.

1. Unless in exceptional circumstances, the Hutton Memorial Medal shall be awarded not oftener than once in every three years; and in no case shall any medal be awarded unless, in the opinion of the Board, some contribution really deserving of the honour has been made.

2. The medal shall not be awarded for any research published previous to the 31st December, 1906.

3. The research for which the medal is awarded must have a distinct bearing on New Zealand zoology, botany, or geology.

4. The medal shall be awarded only to those who have received the greater part of their education in New Zealand or who have resided in New Zealand for not less than ten years.

5. Whenever possible, the medal shall be presented in some public manner.

6. The Board of Governors may, at any annual meeting, make grants from the accrued interest of the fund to any person, society, or committee for the encouragement of research in New Zealand zoology, botany, or geology.

7. Applications for such grants shall be made to the Board before the 30th September.

8. In making such grants the Board of Governors shall give preference to such persons as are defined in Regulation 4.

9. The recipients of such grants shall report to the Board before the 31st December in the year following, showing in a general way how the grant has been expended and what progress has been made with the research.

10. The results of researches aided by grants from the fund shall, where possible, be published in New Zealand.

11. The Board of Governors may from time to time amend or alter the regulations, such amendments or alterations being in all cases in conformity with resolutions 1 to 4.

Award of the Hutton Memorial Medal.

1911. Professor W. B. Benham, D.Sc., F.R.S., University of Otago—For researches in New Zealand zoology.

1914. Dr L. Cockayne, F.L.S., F.R.S.—For researches in the ecology of New Zealand plants.

1917. Professor P. Marshall, M.A., D.Sc.—For researches in New Zealand zoology.

1920. Rev. John E. Holloway, D.Sc.—For researches in New Zealand pteridophytic botany.

1923. J. Allan Thomson, M.A., D.Sc., F.G.S., F.N.Z.Inst.—For researches in geology.

1926. Charles Chilton, M.A., D.Sc., F.L.S., C.M.Z.S., F.N.Z.Inst. —For his continuous researches on the Amphipodous Crustacea of the Southern Hemisphere.

1929. Mr G. V. Hudson, F.E.S., F.N.Z.Inst.—For research in Entomology.

Grant from the Hutton Memorial Research Fund.

1919. Miss M. K. Mestayer £10, for work on the New Zealand Mollusca.

1923. Professor P. Marshall, M.A., D.Sc., F.N.Z.Inst., £40, for study of Upper Cretaceous ammonites of New Zealand.

1927. Miss M. K. Mestayer £30, for research on Brachiopoda and Mollusca.

1928. Dr C. Chilton £50, for research on New Zealand and Antarctic Crustacea.

1928. Mr H. J. Finlay £10, for research on New Zealand Mollusca.

GENERAL INDEX.

Return Date	Return Date